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COMMITTEE ON PUBLICATION OF *MOSQUITO NEWS*

H. F. Gray, Chairman, 1 A Court House, Oakland, Cal.
B. I. Gerry, Massachusetts State Reclamation Board, 41 Tremont St., Boston 8, Mass.
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T. G. Raley, Executive Secretary, 1941 Front St., West, Selma, Calif.
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PAPERS AND PROCEEDINGS OF THE ANNUAL MEETING

OF THE AMERICAN MOSQUITO CONTROL ASSOCIATION HELD JOINTLY WITH THE ANNUAL MEETING OF THE UTAH MOSQUITO ABATEMENT ASSOCIATION, SALT LAKE CITY, MARCH 24–27, 1952

CONTROL OF *AEDES* MOSQUITOES IN TWO RECREATIONAL AREAS IN THE MOUNTAINS OF UTAH[1]

DON M. REES AND LEWIS T. NIELSEN

University of Utah

In certain localities in the mountains of northern Utah mosquitoes of the genus *Aedes* are frequently extremely annoying during early summer. In these localities nine species have been collected: *Aedes cataphylla* Dyar, *Aedes communis* (De Geer), *Aedes excrucians* (Walker), *Aedes fitchii* (Felt and Young), *Aedes impiger* (Walker), *Aedes intrudens* Dyar, *Aedes nearcticus* Dyar, *Aedes pullatus* (Coquillett) and *Aedes punctor* (Kirby). Although any of the nine above mentioned species may be locally annoying, members of the four following species are generally the most abundant and important pests: *Aedes cataphylla, A. communis, A. pullatus* and *A. punctor.*

All of these mosquitoes are produced in a single seasonal brood. The larvae develop in temporary pools formed by melting snow as well as in the water along the protected grassy margins of permanent lakes, ponds and mountain streams.

The larvae hatch from eggs laid the previous summer and usually appear in late April or May at the lower elevations, 6500 to 7500 feet, and throughout June and early July at elevations about 8000 feet. The first adult emergence begins in late May and continues throughout June with peak numbers appearing in early July. By the end of the first week in August the females have disappeared from most areas. Although the average life of the female is only of a few weeks' duration the great annoyance caused by them makes control extremely desirable in mountainous recreational areas which are frequented during the summer by large numbers of people.

Control of these mountain *Aedes* with one effective treatment is possible as these species are produced in a single brood each year. Another factor which favors control is the limited flight of these mosquitoes. Although extended migratory movements of members of some of the above mentioned species have been reported to occur in Arctic regions, observations made by the writers both in Utah and other western states indicate a restricted flight range for these species in timbered mountainous regions. Control has proved effective in Utah if extended one mile beyond the area where control is desired.

A number of workers have attempted control of these single brooded *Aedes* in both Canada and Alaska. Also, Roth *et al.* (1947) have carried on experimental

[1] The writers are indebted to the Salt Lake City Mosquito Abatement District for providing personnel and equipment, to Salt Lake County for purchasing larvicides and to the University of Utah Research Fund for providing travel expenses during part of this study.

control work in Oregon against these species. This account, however, is believed to be the first report in the United States of a successful sustained control program conducted on an area basis.

HISTORY OF CONTROL WORK

In August 1937, an appeal was made by the Girl Scout officials to the Salt Lake City Mosquito Abatement District for assistance in combating pest mosquitoes at Camp Cloud Rim, a summer camp for Girl Scouts near Park City, Utah. The University of Utah was notified and a survey of the area was undertaken under the supervision of the senior author. The region, averaging 9000 feet in elevation, is in the Canadian Life Zone with open forests of spruce, fir and aspen. The forests are interspersed with grassy meadows and small lakes.

The first inspection in June, 1938 revealed larvae and pupae in great abundance. The most typical breeding localities were flooded depressions in meadows, the grassy margins of lakes, the overflow of small streams and in rocky pockets. The source of the water was principally from melting snow. Using a pint dipper as a measure, the larvae and pupae averaged 200 per dip, with extremes varying from 25 to over 1000 per dip. The total area in which control was attempted consisted of approximately two square miles. One hundred and forty gallons of oil were applied over this area, most of it by personnel using 4-gallon knapsack pumps. Although a few adults had emerged before treatment, the results were excellent and the camp officials reported fewer mosquitoes than in any previous season. The effectiveness of the 1938 program was evident at the time of the spring inspection in 1939 when the number of larvae averaged approximately 20 per dip, as compared with 200 in 1938. One hundred and fifty gallons of oil were applied in 1939 with effective results.

In 1940 control work was started at Brighton, a popular summer resort near Salt Lake City at the head of Big Cottonwood Canyon. Brighton, at an elevation of 8720 feet, lies in a large glacial cirque. This area, also in the Canadian Life Zone, is characterized by spruce, fir, aspen, thick willow growths and extensive marshy meadows. A small lake with grassy margins occupies a portion of the area. Several thousand people are present at Brighton during the summer months living in lodges, private homes and public camp grounds. Control operations were instigated as a result of an appeal to the Salt Lake City Mosquito Abatement District by a committee of private citizens, representing the summer residents at Brighton, who stated that the mosquitoes during June and July were unbearable. An inspection of the area on June 10, 1940 revealed great numbers of larvae developing in practically all standing water throughout the area including the grassy margins of the small lake. The total area requiring control comprised approximately three square miles. The larvae were very abundant, averaging 150 to 200 per pint dipper sample. Seventy-five gallons of oil were dispensed by knapsack sprayers. Dense willow growths in the marshy areas made much of the spraying extremely difficult as it was impossible for a man carrying a spray pump on his back to penetrate and thoroughly treat these areas. The results, however, were encouraging as the adult mosquito population was only a fraction of that of the previous years. Control was continued the following year and again the inspection revealed the effectiveness of this program. Areas that had been treated in 1940 contained only 20–50 larvae per dip with an average reduction of 80% as compared with the previous year. In pools which had not been treated in 1940 the numbers still averaged 150 to 200 per dip.

The results of control in 1941 at both Brighton and Camp Cloud Rim were disappointing as biting adults were more abundant than they had been the previous year. This was due to the fact that at both localities an attempt was made to simplify control operations by providing

caretakers and camp employees with oil and spray pumps for application. It was the intention to supply trained inspectors who would instruct the resort personnel on the correct methods of control. Though the inspections were properly made, the spraying was not carried out efficiently and a great many adults emerged. After this experience all control work in these two areas has been conducted by employees of the Salt Lake City Mosquito Abatement District. Control work at both Camp Cloud Rim and Brighton has been continued yearly and in recent years has been extended to include all of Big Cottonwood Canyon below Brighton. This canyon is 15 miles long and contains many public camp grounds, lodges and private cabins. Control methods have been the same as those used at Brighton and have been very effective. Control in this canyon was easier than anticipated due to its contours. The canyon is narrow with steep walls throughout most of its length. The gradient is steep and the main stream moves rapidly with only a few situations occurring which are favorable to mosquito production.

CONTROL MEASURES

Inspection: Careful inspection is of primary importance in the control of mountain *Aedes* in Utah. Because of the great diversity of breeding habitats in a mountainous area it is easy to overlook small pools which are prolific producers of mosquitoes.

It has been a standard procedure each year at both Cloud Rim and Brighton to conduct an intensive inspection throughout the entire control area before the application of larvicides. This vigilance has increased the effectiveness of control as new pools have been located and treated yearly.

Drainage: Drainage has been used to a limited extent at both Camp Cloud Rim and Brighton. It has been of value in lowering the water level in some of the large breeding areas, but is of secondary importance in overall control. Drainage in mountainous areas is inadequate due to the fact that the gradual melting of snow, which may last over a period of several weeks, can supply a pond with sufficient water to hatch eggs even though the pond may be continually draining. Drainage in situations like this may be unwise as it may cause distribution of larvae over a wider area. There are situations where drainage may be used to good advantage, but the practicality and location of drains must be carefully studied by experienced personnel before this form of control can be utilized. It has been the experience in Utah to date, that the cost of constructing and maintaining an adequate drainage system in mountainous areas where heavy snowfall occurs, is generally greater than the cost of a single effective larviciding program.

LARVICIDES:

Oil: Petroleum oil was the only larvicide used in control operations from 1938 until the summer of 1949. Though now largely replaced by DDT, oiling has produced excellent results in the past and still may be useful in certain situations where pupae are present or where the use of DDT may be objectionable. The best results against mountain *Aedes* were obtained with light oil of good quality. The spreading quality of the oil is especially important in the mountains where the temperature of the water produced from melting snow is often very low. In Utah an oil larvicide consisting of 97% No. 2 fuel oil and 3% cresol has been used. Cresol, which contains 12% coal tar acids, substantially increases the toxicity of the fuel oil. Oil does not have the residual effect of DDT, but it does cause a reduction in the number of larvae which appear in the same pools the following year. It has been observed at both Camp Cloud Rim and Brighton that pools treated with oil show a 50% to 80% reduction in the number of larvae occurring the following season. Herms and Gray (1944) report similar observations in the mountains of California and believe that oiling is a definite deterrent

to deposition of eggs by mountain *Aedes* mosquitoes. This is probably true, but it should be noted that any larvicide which kills as effectively as oil will greatly reduce the potential number of egg laying females, and should naturally cause a reduction in larvae the following year. This is especially true for mountain *Aedes* which produce only one brood yearly and apparently have a limited flight range.

DDT: One of the greatest problems in the control of mountain *Aedes* is to reach the mosquito-producing water before the adults are on the wing. Snow-blocked roads often delay work until effective control becomes very difficult. This problem has been experienced at Camp Cloud Rim where the road, because of snow, is usually not open until the larvae are in the late instars or have pupated. The solution to this is the use of a pre-hatch larvicide which can be applied in the fall while the roads are open.

In this program DDT was first used as a pre-hatch larvicide in September, 1949 at Camp Cloud Rim. At this time one of the most prolific mosquito-producing areas was divided into several small plots. These were sprayed with an aqueous solution of DDT at the rates of .2, .3 and .4 lbs. of DDT per acre. All sprayed plots had adjoining untreated control plots. On June 10, 1950 all of these plots were inspected. Those plots treated with .3 and .4 lbs. DDT per acre showed a complete absence of larvae and plots with .2 lb. of DDT per acre contained only an occasional larva. All untreated control plots contained larvae averaging from 10–50 per dip. On June 15, 1950, using the same concentrations of DDT as above, the entire control area at Camp Cloud Rim was treated. A number of pools were left untreated as controls and the pools sprayed in September 1949 received no further treatment. The summer of 1950 was unquestionably the most successful season since the inception of control work at Cloud Rim and very few adults were reported by camp personnel. No pre-hatch

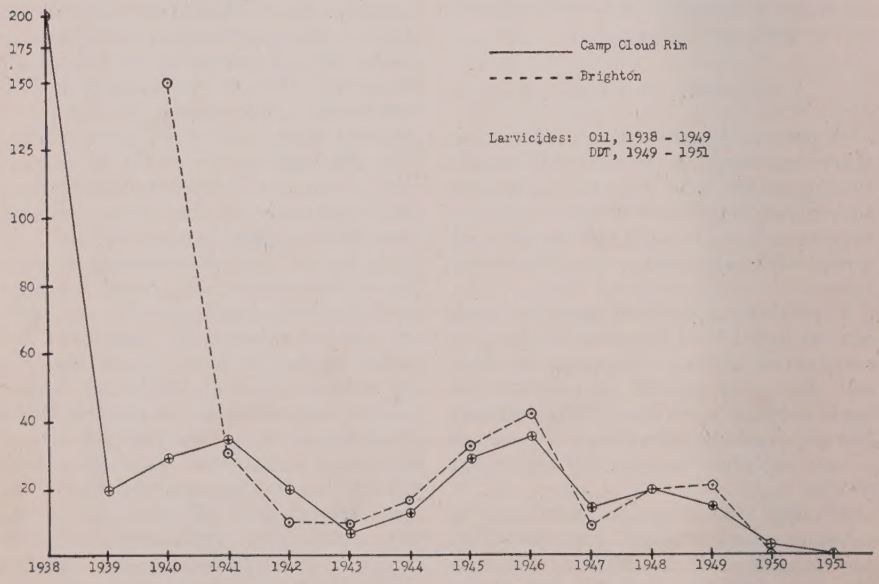

FIG. 1. Reduction in mosquito larvae in water treated with larvicides as determined by the average number of larvae obtained in a pint dipper during all inspections. (Increase in larval production during years of 1944, 1945 and 1946 due to curtailment of control activities during wartime.)

work was attempted during the fall of 1950. In June, 1951 an intensive inspection substantiated the incomplete results of the previous year. Larvae rarely were found in areas treated with .3 and .4 lb. of DDT per acre and relatively few were found in areas treated with .2 lb. per acre. All untreated plots contained numerous larvae except those originally treated in the fall of 1949. These for the second year produced no larvae.

Pre-hatch work at Brighton was begun in April, 1950. Brighton is a winter skiing resort and it is possible to gain access to the region at any time during the year. The pre-hatch treatments were conducted here in the same manner as at Camp Cloud Rim using the same concentrations of DDT. At Brighton, however, a 10% dust applied at the rate of 1 lb. per acre also was used and both the spray and dust were applied on the snow over known breeding areas. This method of pre-hatch treatment for snow mosquitoes had been previously reported from Oregon by Roth *et. al.* (1947), although they used a much higher concentration of DDT. This type of treatment was particularly effective at Brighton. In previous years the dense willow growths had made spraying extremely difficult and of limited effectiveness. During the winter as the result of heavy snows the willow thickets were covered and it was a simple matter to spray or dust DDT on the snow over them.

An inspection in June, 1950 revealed almost identical results with those at Camp Cloud Rim. All DDT treated areas showed larval reductions in excess of 98% when compared with untreated areas. All untreated control areas contained larvae ranging from 25 to 50 per dip. These control pools were sprayed with .3 lb. DDT per acre and 100% kill was obtained except in a few pools which contained pupae. In these cases the spraying was only 40–70% effective. In June, 1951 an inspection revealed that all pools treated in the spring and summer of 1950 showed reductions of larvae from 98–100% over previous years. No additional treatment was required at Brighton in 1951 except for a few new localities discovered when control measures were extended over a slightly wider area. Several inspections made during June and July, 1951, revealed almost a total absence of biting adults.

Tossits: One of the extremely valuable aids in the control of snow mosquitoes in Utah has been the use of "Tossits" manufactured by SENTCO Inc., of West Palm Beach, Florida. These are small gelatinous capsules about 20 mm. in diameter, which contain 12% DDT and 4½% BHC. The combination of DDT and BHC makes them very effective on all larval stages and pupae. When immersed in water they soon release the chemicals which spread over the water surface very rapidly. Under normal use each Tossit is reported to have a killing effect in 750 sq. feet of open, unobstructed water surface. In our experience in mountainous areas where the water usually contains vegetation and a considerable amount of organic matter they are most effective when applied at the rate of 1 per 100 sq. feet of water surface.

TABLE 1. Comparison of pools treated at Camp Cloud Rim and Brighton before and after the application of DDT.

Locality	Number of pools treated at first inspection	Maximum number of pools treated with oil, 1949	Number of pools requiring treatment in 1951 after DDT applications
Camp Cloud Rim	46 (1938)	62	9
Brighton	79 (1940)	107	7
Totals	125	169	16

In this program Tossits were used under a wide variety of conditions. Their chief value is attained when used on small pools located during inspections. An inspector can carry a quantity of Tossits very easily through rough heavily vegetated mountainous terrain and can treat an extensive area which would be extremely difficult to treat with knapsack pumps. Their use is by no means limited to small pools. They have been used successfully along lake margins, and in one instance a pond of about 2000 sq. feet of surface was treated successfully with Tossits distributed in the snow over the ice covering the pond.

It appears that Tossits have a good residual effect. In most cases pools treated with Tossits in June, 1950 at both Camp Cloud Rim and Brighton showed a reduction in larvae in 1951 comparable to ponds sprayed or dusted with DDT.

SUMMARY AND CONCLUSIONS

Control of mountain *Aedes* mosquitoes has been carried on successfully in Utah for thirteen years. Although other workers have attempted experimental control against mountain *Aedes* (Roth, *et. al.* 1947) this is believed to be the first report of an effective sustained control program against these mosquitoes on an area-wide basis.

This program was conducted in two recreational areas in the Wasatch Mountains near Salt Lake City. Both of these localities are in the Canadian Life Zone and average 8500–9000 feet in elevation. The principal mosquito species in both regions are *Aedes cataphylla, Aedes communis, Aedes pullatus* and *Aedes punctor.* The following analysis of the results of this control program may be helpful in establishing control in other mountainous localities where pest *Aedes* species occur:

1. The success of mosquito control depends primarily upon the thoroughness with which inspections are made to locate all water producing larvae. This is especially true in controlling *Aedes* in mountainous areas as the larvae occur in diversified situations and the nature of the terrain is conducive to the formation of new mosquito producing sites.

2. Drainage is generally of limited usefulness in mountainous regions where deep snow accumulates in the winter and gradually melts in the spring and early summer. In the Wasatch Mountains of Utah the cost of constructing and maintaining an adequate drainage system has proved to be considerably greater than that of an effective larviciding program.

3. The use of a light petroleum oil of good spreading quality is effective on all immature stages of mountain *Aedes.* A No. 2 fuel oil with cresol added to increase the toxicity was used with good results in these recreational areas for several years. Though inferior to DDT in its residual effect and in ease of transportation and application, it nevertheless is an effective larvicide.

4. DDT in both spray and dust form has proved to be very effective against mountain mosquitoes in Utah. Concentrations of .3 and .4 lb. per acre for the spray and 1 lb. per acre for the dust have produced excellent results with residual effects lasting at least one year. The use of the spray has proved more desirable than the dust because it can be used effectively in smaller quantities and can be easily transported in a concentrated soluble form and mixed in the desired proportions with water at the site of application. It also can be applied more uniformly than dust. Although DDT may be applied directly to pools containing larvae and pupae, better results have been obtained when used as a pre-hatch larvicide. In this way areas which produce larvae can be treated in late summer or fall, and the danger of snow blocked roads and trails preventing early treatment in the spring is avoided. If the control areas can be reached during the winter months or in early spring it is often desirable to treat the snow over known mosquito producing sites. This method has proved especially useful in the Wasatch Mountains of Utah where many of the most prolific mosquito producing areas occur in dense willow growth, which are extremely

difficult to penetrate and treat. In the winter these willow growths are covered by heavy snowfall and it is possible to effectively pre-hatch the area on the surface of the snow.

5. "Tossits", the small gelatinous capsules containing 12% DDT and 4½% BHC have proved extremely useful in these recreational areas. Each "Tossit" will effectively treat about 100 square feet of water surface. They can be used in almost any type of situation and have a good residual effect. In this program they were especially valuable when carried by inspectors and used in treating pools found in rugged terrain that would be difficult to reach and treat with knapsack pumps.

6. Some of the other hydrocarbons have been used experimentally in these two recreational areas with promising results. To date it has been unnecessary to use other larvicides extensively, as DDT, supplemented with Tossits, has produced complete control in the Brighton area and has produced excellent results at Camp Cloud Rim and vicinity.

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CONTROL OF BITING GNATS IN NORTH SALT LAKE CITY, UTAH (DIPTERA : HELEIDAE)

DON M. REES AND JAMES V. SMITH
University of Utah, Salt Lake City, Utah

A program for the control of the biting gnat—*Leptoconops kerteszi* var. *americanus* was conducted in North Salt Lake City, Utah during the spring of 1949, 1950 and 1951. The results of the work in 1949 have been published (Rees and Smith, 1950). The control program was continued in 1950 with marked improvements and was repeated in 1951 with complete success, as measured by the absence of gnat annoyance in the area. The program consisted of two phases: first, determination of the location and size of the area in which the gnats are produced, and second, the determination of the most effective and economical methods of control.

SURVEY

The first phase, that of determining the location and size of the area in which the gnats are produced, was at first extremely difficult, time-consuming and expensive. The gnat-producing areas involved, as eventually determined are shown in Fig. 1. The larvae of this gnat develop in moist soil and do not appear on the surface until the time of pupation. In the first surveys that were made to locate the larvae, soil samples were taken at measured intervals, then washed, screened and examined in the laboratory under magnification. This was a slow, laborious method and too expensive to be practicable.

In 1950 it was observed that when the larvicide was applied to the surface of the ground, just prior to the time of pupation, the larvae exposed themselves, and squirmed around for several minutes before dying. Under these conditions they were readily visible to the unaided eye.

As a result of these observations several different insecticides such as DDT, lindane, chlordane, toxaphene and rothane were used in water emulsions of 1.0, 2.5, 5.0, and 10.0 percent, to determine the most effective insecticide and concentra-

tion to be used for this purpose. There was no significant difference in the effects of the insecticides tested, but the length of time required to produce maximum activity of the larvae apparently varied with the concentration of the larvicide. The following table is general and may be applied to each of the insecticides tested.

TABLE 1

Solution Concentration	Length of time of activity after application	Time of maximum activity after application
Percent	Minutes	Minutes
1.0	5 to 25+	12+
2.5	1 to 20+	8+
5.0	1 to 9+	2+
10.0	1 to 5+	1+

Depending on the time required before a treated sample could be checked by observation, 1.0, 2.5, and 5.0 percent solutions worked equally well in making such a survey. In most instances a 10.0 percent solution apparently killed or inactivated the larvae before they exposed themselves for a sufficient length of time for accurate detection. As a result of these tests, a 2.5 percent solution of DDT was adopted for use in the chemical method used in 1951 for locating the gnat larvae in the soil. The use of this concentration allowed ample time for an observer to follow the person applying the larvicide and check each sample about eight minutes after application, at the time of maximum activity of the larvae.

In using this chemical spot-treatment method in 1951, it was found advantageous to remove the vegetation with a two-edged triangular weed cutter before applying the insecticide. The insecticide was then applied with a hand pump equipped with a fine nozzle. Square-foot areas were sprayed until the ground was thoroughly wet. The location was marked with a stake and examined for larvae five to ten minutes after the insecticide was applied.

To check the accuracy of this survey method frequent samplings were made in areas known to contain larvae. The method always worked if the larvae were near the surface of the ground ready for pupation. The location of the larvae and therefore the time for running the chemical survey was determined by examining soil samples taken periodically until it was determined that the larvae were susceptible to chemical treatment. As all the larvae in the area developed at about the same rate the entire area was treated as soon as possible after the chemical survey. This chemical spot-treatment method developed in 1951 made it possible to complete the larval survey in about one-eighth the time and expense required to complete the survey in 1949 and 1950 by the soil sample method.

The second phase of the program was that of eliminating the gnats, using the most effective and economical methods. As reported (Rees and Smith, 1950), DDT applied at the rate of one pound per acre in 28 gallons of water is very effective in destroying the larvae by a direct kill. Since the larvae are concentrated in the soil in certain limited areas while other areas are free from larvae, it is feasible to treat the soil containing larvae with DDT as soon as the limits of the gnat-producing area are determined. The DDT solution was applied with power equipment when possible and by hand when necessary.

The ground where the gnats develop has a high water content in the spring of the year, making it impractical to treat some of it with ground equipment. Later in the season the water table recedes and the ground dries out allowing the use of heavy equipment. This led to the effective use of DDT applied in the fall as a pre-hatch treatment. The areas treated were known to contain larvae the previous spring, and DDT as a pre-hatch was applied in November at the rate of two pounds per acre in about 28 gallons of water. On the 30 acres treated in this manner in the fall of 1950, no gnat larvae were found in the spring of 1951, nor were adult gnats taken in the box traps located on this area during the season.

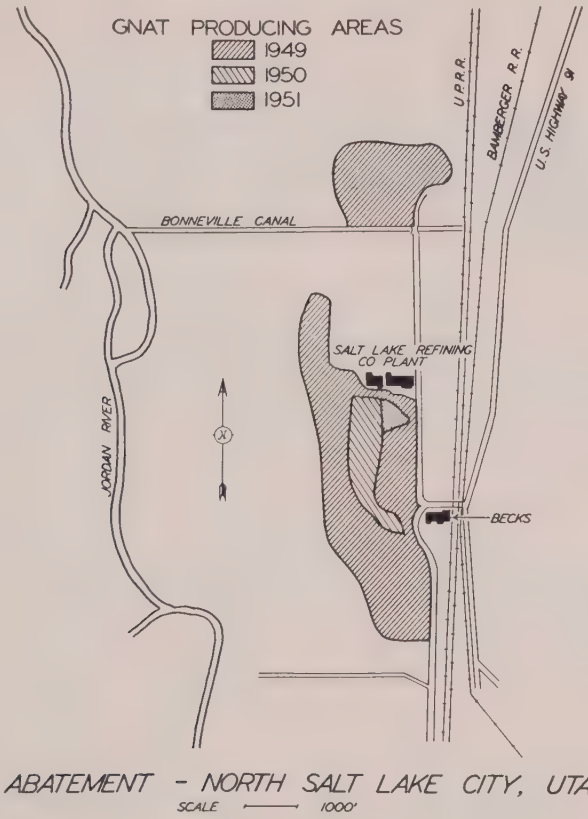

FIG. 1. Gnat-producing areas involved in the tests described.

Naturalistic methods of destroying gnat larvae such as by soil cultivation and lowering the water table are under investigation with promising results to date.

Box traps as described in the previous published report have been used each year to collect the emerging adults. This procedure is a means of determining the productiveness of different areas and the effectiveness of the control methods.

The accompanying graph (Fig. 2) illustrates the effects of the control program from 1949 to 1951 inclusive, as determined by the number of acres producing gnats and the number of adult gnats emerging from the treated and untreated area according to box trap collections. Each trap covered three square feet of breeding area.

SUMMARY

A project for the control of biting gnats was conducted in North Salt Lake City, Utah, during the spring of 1949, 1950, and 1951. A study of the biology and habits of these gnats has also been in progress throughout the year from the spring of 1948 to the present. During this study a chemical spot-treatment method for a larval survey was developed which makes it possible to complete the sampling in the field in a relatively short time, eliminating laborious washing, screening and microscopic examination of soil samples in the laboratory.

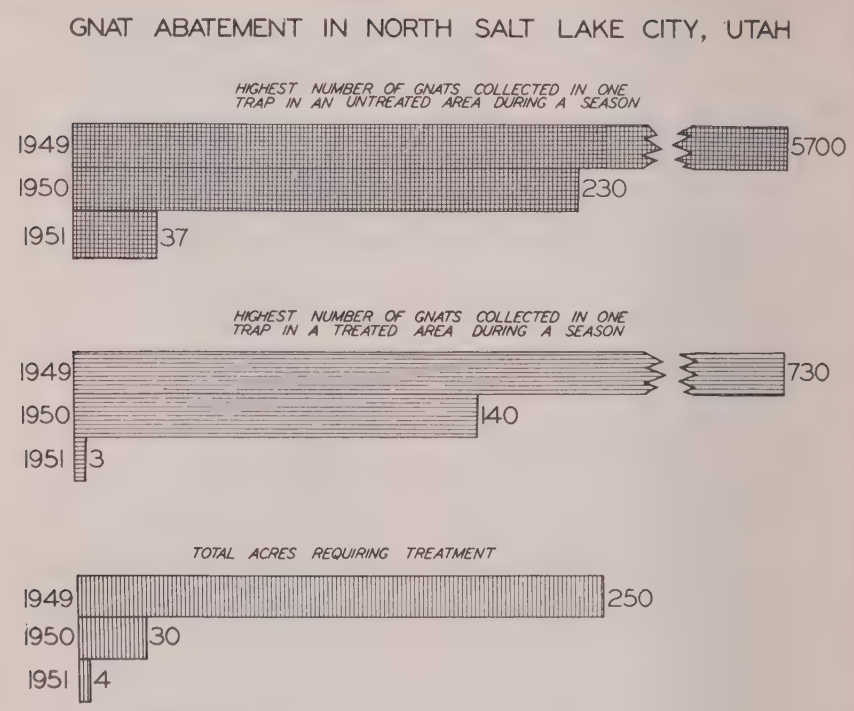

FIG. 2. Effects of gnat abatement program in 1949, 1950 and 1951.

Chemicals including DDT, lindane, chlordane, toxaphene and rothane were used on an experimental or extended basis for soil treatment, to destroy the gnat larvae. These chemicals were applied in different concentrations for a direct kill, and as a pre-hatch or residual. In addition, soil cultivation, such as plowing and disking, as well as drainage, were applied in an attempt to prevent gnat production. The number of gnats, as a result of this control program, has been substantially reduced each year until in 1951 the gnats, as an annoyance factor, were eliminated from the controlled area.

CONCLUSIONS

1. The biting gnats in North Salt Lake City, Utah, have been effectively controlled, over a three year period, as the result of a gnat control program.

2. The control measures developed have proved to be effective and practical and may eventually eliminate the gnats from this area.

3. The effective and practical control measures developed consist of a chemical method for determining the presence of the larvae in the soil and the application of one pound of DDT per acre for a direct kill or two pounds per acre as a pre-hatch treatment.

4. Results obtained to date in preventing gnat production by soil cultivation and drainage are promising.

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NON-HUMAN MALARIA IN MOSQUITOES AND THE ENGLISH SPARROW, *PASSER DOMESTICUS* LINN., IN THE VICINITY OF SALT LAKE CITY, UTAH

A. W. GRUNDMANN, H. D. NEWSON AND R. G. WARNOCK
Department of Invertebrate Zoology and Entomology, University of Utah

This contribution is part of a continuing investigation into the incidence and distribution of non-human malaria present in northern Utah and the possible correlation of that incidence with mosquito abatement practices. The report includes results obtained by means of blood slides prepared from birds of a sample collection of English sparrows, *Passer domesticus* Linn., and by dissections and examinations of female culicine mosquitoes from the same area from which the birds were collected. Additional species of passerine birds are being investigated, but inasmuch as the results are not conclusive, they were not included. The species of mosquitoes which were examined and included in this report are those most prevalent within this region: namely, *Culex pipiens* group,* *C. tarsalis* Coq., *Aedes vexans* Meigen, and *A. dorsalis* Meigen.

In the English sparrows examined, all smears containing plasmodia-like sporozoans which were infecting red blood cells were considered as being indicative of the presence of avian malaria. In the species of mosquitoes examined, it is possible that other kinds of sporozoans may also produce stages similar to those of the Plasmodia, hence, all specimens here considered as positive may not necessarily be indicative of malaria. Investigations to determine the kinds of sporozoans present in birds and mosquitoes from this region have been limited, but since no forms other than Plasmodia have been reported, positives have been regarded as Plasmodia in this report.

As far as could be determined no previous investigation of this type has been conducted in the intermountain region. Reeves (1950) made somewhat similar studies in Kern County, California, and in Yakima, Washington. In these studies he found *Culex tarsalis* to have a natural infection of 16.3 per cent in 1946 and 8.8 per cent in 1947 in Kern County and "less than five per cent" in Yakima, Washington. To our knowledge, no previous field studies have been conducted for species of the genus *Aedes*. Mosquitoes belonging to a number of species of this genus have been experimentally infected with malaria in the laboratory, but no information concerning their natural infectivity is available. *Aedes vexans* which is fairly prevalent in this area, has been experimentally infected (Cantrell and Jordan, 1945). *Aedes dorsalis,* the most abundant pest species within this area, has not been reported, however, either as being naturally or experimentally infected by these sporozoan parasites. The present work is the first to make such a report with reference to *A. dorsalis*.

METHODS

The mosquitoes were collected alive from humans and domestic animals, by means of New Jersey type light traps, and aspirator tubes. Light traps were made more effective by means of crushed dry ice which was suspended over them in cheesecloth bags, as advocated by Rudolphs (1922). Results obtained indicated increased catches of female mosquitoes where this procedure was followed. The traps were usually operated from sunset until midnight and an average catch of approximately 150 adults was obtained in areas where no abatement of mosquitoes was operative. In comparison, the average catch was seven to ten adults in abated areas. On the few occasions when the traps were allowed to operate from sunset to sunrise, only a slight increase in

* The *Culex pipiens* group includes *C. pipiens, C. erythrothorax* and *C. salinarius.*

the number of mosquitoes was noted, indicating that the majority were trapped during the early evening hours and that continued operation of the trap beyond midnight yielded few additional insects. A cage, constructed of 3/16 inch welding rod, 4 x 4 x 10 inches in size, and covered with bobbinet, was attached to the lower opening of the trap. This cage was removed each morning.

The mosquitoes were kept in quart fruit jars in groups of ten until examined. Each group was anesthetized with tobacco smoke and each insect was then identified to species and individually dissected. The midguts were mounted on glass slides in saline and examined under low and high power for the presence of oocysts. Further examination of the salivary glands was carried out on all individuals possessing oocysts. In addition, the salivary glands of a number of specimens selected at random and not demonstrating oocysts were examined. The dissection technique used was that described by Russell *et al.* (1946).

The sparrows examined were either obtained through the use of U. S. Department of Agriculture type traps made of hardware cloth and baited with wheat, or shot with .22 caliber dust shot. Blood samples were generally taken from the jugular vein in the neck. In cases where this was not possible, blood was obtained from the liver or heart on autopsy. Slides were air dried and fixed for 30 seconds in methyl alcohol and stained with Giemsa stain using standard technique. In order to avoid the transfer of blood cells between slides, they were either stained singly or in small numbers widely separated from each other in the staining jars.

Discussion and Results

Specimens of mosquitoes and birds were collected from the same general areas, and as often as possible from the same localities. In order to provide a basis of comparison, specimens were collected from localities both within and outside of areas in which mosquitoes were abated. The region selected for the study was divided into three general areas: (1) Salt Lake City proper, under abatement; (2) the area north of the city in Salt Lake and Davis counties; (3) the area south of the city, primarily around the Taylorsville townsite. The latter two areas are largely unabated.

A total of 209 birds and 1072 mosquitoes were examined for malarial parasites. The results are presented in Table 1. The birds examined were seasonally distributed, with some taken at all seasons of the year. Of those birds taken at Salt Lake City, 49 were collected in Liberty Park which is centrally located. All of these birds proved to be uninfected. The remainder of the birds, seven in number, taken from other parts of the city, included one infected bird. The lack of infection in birds taken at Liberty Park may be explained by the fact that they probably do not migrate since ample food and protection are available within the park at the Tracy Aviary, and thus they do not come into contact with infected mosquitoes from other regions. Mosquitoes taken at this location (*Culex tarsalis* Meigen) also proved to be uninfected. The highest incidence of infection in both birds and mosquitoes occurred in the Taylorsville region of south Salt Lake County. Here 26 per cent of the birds and 14.9 per cent of the mosquitoes were found to be infected. Taylorsville is a poultry producing area and is outside of the mosquito abatement districts.

The north Salt Lake County area consists of an agricultural and stock raising area, part of which is in the Salt Lake City Mosquito Abatement District. In addition, the area includes the Farmington Bay Bird Refuge and numerous private duck clubs which provide a large wild bird population. The survey of this area showed 9.3 per cent of 64 birds and 10.9 per cent of 155 mosquitoes to be infected.

Species of Malaria. Of the species of malaria present in the birds, one was determined to be *Plasmodium relictum* Grassi and Feletti, and was confirmed by Dr. Carlton M. Herman of the Patuxent Refuge, Laurel, Maryland. The other

species was tentatively identified as *P. cathemerium* Hartman. The latter species frequently occurs in sparrows in this country.

TABLE 1.—The Incidence of Plasmodia in the English Sparrow and Plasmodia-Like Organisms in the Mosquitoes of the Salt Lake Region

Location	No. of Mosq. Examined	No. of Mosq. Infected	Per cent of Infection of Mosq.	No. of Birds Examined	No. of Birds Infected	Per cent Infection of Birds
Salt Lake City	96	9	9.35%	56	1	1.78%
North Salt Lake County	155	17	10.9 %	64	6	9.37%
South Salt Lake County	821	122	14.85%	89	23	26.0 %

Results. The results of the dissections of mosquitoes are shown in Table 2. Infected salivary glands were not present in every individual which had a positive mid-gut infection, but since the age of the infection is not known this is not significant. Some members of each of the species which had positive mid-gut infection also had infected salivary glands. This indicates that each of the four species found with mid-gut and salivary gland infections are potential vectors of malaria-like organisms. No infected salivary glands were found in the absence of mid-gut infection.

Boyd (1940) found good correlation between the incidence of mid-gut infection and salivary gland infection, but other workers have expressed the opinion that mid-gut infections do not necessarily result in the production of viable sporozoites. The results of this survey could not be cited as evidence for either of the above views because it is not known which of the infections observed were old enough to have progressed to the sporozoite stage.

Some of the *Aedes vexans* captured during the late part of the summer were very heavily infected. When infected, individuals of this species seemed to be parasitized to a much greater degree than were those of other species.

Discussion. Similar studies have been made in the United States, but most of them have been restricted to *Anopheles* species. The only similar studies made in the western United States, with which the authors are familiar are those made by Reeves and Hammon in Kern County, California, and Yakima Valley, Washington. The infection rates for Kern County compare favorably with those found in *C. tarsalis* from Salt Lake County in 1948 and 1949.

TABLE 2.—Summary of Results of Survey (1948 and 1949) *

Species	No. Examined	No. Infected	Per cent Infection
Culex pipiens	99	18	18.2
Culex tarsalis (1948)	209	19	9.1
Culex tarsalis (1949)	200	35	17.5
Aedes dorsalis	355	48	13.5
Aedes vexans	172	28	16.2

* A small number of other species was examined with negative findings.

Huff (1931) reported a natural malarial infection rate in *Culex pipiens* of 28.1 per cent in 160 dissections, but no information was given regarding the locality in which the mosquitoes were captured. This infection rate is considerably higher than was found among the same species in Salt Lake County.

As far as could be determined, no

previous study has been made of the natural malarial infection rates among *Aedes* mosquitoes in the United States. Several species of this genus have been infected experimentally in the laboratory, but no information is available regarding their natural incidence of malarial infection. *Aedes vexans* has been reported to have been infected in the laboratory, but as far as can be determined, *Aedes dorsalis* has never been reported either to have been infected experimentally in the laboratory or to possess a natural infectivity.

With such a high natural infection rate present in *Aedes dorsalis, A. vexans, Culex tarsalis* and the *C. pipiens* group in Salt Lake County, curiosity is aroused as to the sources of these infections. It has been demonstrated that infection exists in the English sparrows. Other birds, as well as reptiles, should be investigated as possible sources of infection. No data are available which show conclusively that the above indicated mosquitoes feed on English sparrows. The only information available giving any knowledge regarding the natural feeding habits of culicine species in the western United States was obtained by Hammon and Reeves (1947) and Hammon *et al.* (1945) in Kern County, California, and by Reeves and Hammon (1944) in Yakima Valley, Washington. By means of precipitin tests, they determined that up to 55 per cent of the *Culex pipiens* and the *C. tarsalis* tested in those areas had fed on certain wild birds. These same studies indicated that most of the *Aedes* examined had fed upon large mammals, i.e., horses, cattle, and sheep.

Pending the outcome of further work on the subject, little of certainty is known regarding the possible sources of infection of these four species of mosquitoes, and much remains to be done before a clear picture of the epidemiology of non-human malaria in this area can be obtained.

The present evidence appears to indicate, however, that lower infectivity exists in both mosquitoes and birds collected from areas in which mosquitoes are abated than from those collected in areas not so controlled. This is indicated by the 14.85 per cent infectivity in mosquitoes in the south Salt Lake region, which is uncontrolled, as opposed to the 9.35 per cent in the controlled area. This is further indicated by the fact that both mosquitoes and birds taken in the central part of the city were completely negative. The north Salt Lake region, partially under control, showed a medium of 12.8 per cent.

SUMMARY

An investigation of the non-human malaria present in adult female mosquitoes and in the English sparrow (*Passer domesticus* Linn.) was carried on in the Salt Lake City region during 1948 and 1949. Four of the most common and important culicine mosquitoes were found to be infected. These were *Culex pipiens* 18.2 per cent, *Culex tarsalis* 9.1 per cent, 1948 and 17.5 per cent in 1949, *Aedes vexans* 16.2 per cent; *A. dorsalis* 13.5 per cent. This report constitutes the first record of infection of *Aedes dorsalis*. Other species investigated proved to be uninfected.

The blood of 209 sparrows was examined for parasites. The sparrows were collected from three general areas, (1) Salt Lake City proper, an area under mosquito abatement, (2) north Salt Lake County, partly under mosquito abatement, and (3) south Salt Lake County, with no abatement. The mosquitoes were collected from the same general localities. Several species of malarial parasites were noted. One was identified as *Plasmodium relictum*. The other was tentatively identified as *P. cathemerium*. The birds from the Salt Lake region had an infection rate of 1.78 per cent, those from south Salt Lake 26 per cent and from north Salt Lake County 9.37 per cent, indicating that mosquito abatement may be a factor in reducing the incidence of infection in birds and mosquitoes.

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THE TWENTY-FIFTH YEAR OF MOSQUITO CONTROL IN GREATER WINNIPEG, CANADA. 1951.

E. I. STANSFIELD

Manager, Greater Winnipeg Anti-Mosquito Campaign, Manitoba

Winnipeg is situated in Manitoba, Canada, midway between the Atlantic and the Pacific coasts, 460 miles north of Minneapolis, at the confluence of the Red and the Assiniboine Rivers. The Greater Winnipeg Anti-Mosquito Campaign controls an area of 250 square miles containing a population of 350,000 people, centering on the City of Winnipeg. The average annual precipitation is 20.47 in., including 5 in. of moisture from snow during the winter months. Our very rapid spring thaw in April results in the formation of many mosquito breeding places. In the warmer part of the summer flying mosquitoes may appear one week after eggs have been covered by rain water.

During the Red River flood of 1950 this campaign used methods and machinery for controlling mosquitoes which helped us considerably in 1951. In 1951 a Lawrence Aero-Mist was added to the two Tifa foggers to round out our heavy insecticide equipment. Where use of these mechanical applicators was not possible, manual treatment by pressure sprayer was used.

We used 6% DDT water emulsion for water surfaces, and 5% DDT oil solution for fogging, and waste oil applied in certain instances. Water surfaces included ditches, clay pits, sloughs, river banks and marshy land. Fogging encompassed residential districts with special attention to parks, golf courses, community clubs and river banks. This two-way attack against mosquito larvae in the water and the flying adult in the air was again successful in providing effective control against mosquitoes for an 8-mile radius from the center of the city.

Rainfall between April and July was below normal, whereas August rains were 71% above normal. This worked to our advantage in the early part of the season.

Ditch maintenance was carried out by man power and by spraying willows with the power sprayer using 2, 4-D at 0.9 lb. per acre. This gave effective control of willows.

Pre-season application of DDT. As an

integral part of our anti-mosquito program, experimental work has been done since 1947 to test the prospects of controlling larvae in the early spring and summer by applying DDT during the previous fall, as follows:

During September, 1947, 2½ acres of dry marsh were sprayed by hand using from 2–5 lbs. DDT oil solution per acre. During May, 1948, larvae were observed in the control plot, but in the treated plots larvae did not appear until 9 weeks later. The ground at this time was still covered with water.

During September, 1948, 6 acres of water in clay pits were sprayed manually with 3% DDT emulsion, (4 lbs. DDT per acre). No larvae appeared in 1949 in pits containing water throughout the entire season. In the same year 17 acres of dry marsh were also sprayed manually with DDT emulsion, (1.5 lbs. per acre). Larvae appeared in the control plot in April, whereas they did not show up in the treated plot before the water dried up at the end of May. In the latter instance heavy rain on August 13 promoted renewed breeding, observed on August 22 in the treated area.

During September, 1949, 8 acres of clay pits were sprayed (6% DDT emulsion at 3.75 lbs. DDT per acre) and no larvae appeared in 1950. The pits contained water until the end of the season. Also in September, 1949, 57 acres of dry swamp land were sprayed by machine (6% DDT emulsion at 3.2 lbs. DDT/acre). Larvae appeared in the control plot on June 21, but none appeared in the treated plot.

During September, 1950, 30 acres of dry marsh were sprayed by machine, (12% DDT emulsion at 3.7 lbs. DDT per acre). This area dried up by the end of May and no larvae had appeared up to that time.

During September, 1951, 2 acres of slough were sprayed by machine (6% DDT emulsion at 3 lbs. DDT per acre). This area will be under observation in 1952.

The campaign executive felt that the foregoing observations should be tested more exactly by chemical and bioassay methods. Funds and personnel not being available to the campaign for this type of work a co-operative set-up was arranged between: (a) The Division of Entomology, Department of Agriculture, Canada; (b) The Department of Health and Welfare, Province of Manitoba, Canada; and (c) The Greater Winnipeg Anti-Mosquito Campaign, City of Winnipeg, Manitoba.

By kind permission of Dr. H. E. Gray, Head, Stored Product Insect Investigations, Ottawa, Mr. B. Berck, chemist in the Winnipeg laboratory was allowed to act in an advisory capacity. Dr. H. M. Malcolmson, Director of Environmental Sanitation, Manitoba Department of Health and Welfare, allowed us to use laboratory facilities under the supervision of Mr. W. M. Ward, Chemist-in-charge, in which to carry on the necessary experiments. The mosquito campaign staff collected specimens and did the tests in the laboratory under the above supervision.

On April 30, 1951, samples of water, vegetation and soil were taken from an area that had been sprayed by machine in September, 1949, and also in 1950 at 3.2 lbs. and 3.7 lbs. DDT per acre respectively.

A second round of samples of soil and vegetation were taken on July 20 and analysed for DDT. By this time the water had dried up.

Laboratory findings. In April *vegetation* samples averaged 32.7 p.p.m. DDT, ranging from 4 to 39.8 p.p.m., while in July the sample contained 17.3 p.p.m. DDT.

In April *soil* samples averaged 0.922 p.p.m. DDT, ranging from 0.155–5.4 p.p.m. DDT, whereas in July soil samples averaged 0.334 p.p.m. DDT, ranging from 0.116–0.552 p.p.m. DDT.

In April *water* samples averaged 0.0297 p.p.m. DDT, ranging from 0.0073–0.1065 p.p.m. DDT.

The April *moss* sample contained 15.9 p.p.m. DDT, whereas the July moss sample contained 14.9 p.p.m. DDT.

Substantial amounts of DDT were therefore found in the water, on vegeta-

tion and in the soil of the treated area. Water samples contained a substantial amount of DDT, but this was much less than that of soil and vegetation. The DDT content of the vegetation and the soil was reduced from April to July, but that of the moss appears to have changed very little.

Bioassay. The important question of the larvicidal effectiveness of the DDT in the samples tested chemically also engaged our attention. Dr. C. R. Twinn, Head, Veterinary and Medical Entomology Unit, Ottawa, kindly supplied eggs of *Aedes aegypti* L. mosquitoes with recommendations for laboratory rearing of the larvae for use in the bioassays. Filtrates and solutions of the field samples were used.

These tests were inconclusive, as in some cases where third and fourth instar larvae were used no mortality resulted after 24 hours exposure although chemical tests of the field sample showed up to 36 p.p.m. DDT. On the basis of the above laboratory findings it seems reasonable to suppose that the DDT present in the samples was not sufficiently transposed to the water, within the limits of the methods of bioassay that were used.

Aedes aegypti larvae were also used to test water samples taken from ditches and clay pits which had been sprayed by machine with 6% DDT emulsion in routine work during the summer. Larvicidal effectiveness was noticeable from 3–6 weeks after spraying, both when the sample came from the surface and from the bottom.

Hatching efficiency of Aedes aegypti *eggs.* It was found that 6 out of 10 filter papers with eggs attached produced no larvae when soaked with distilled water. In the course of reading through literature relating to this subject, work done by Gjullin, Yates and Stage was noted in which amino acids and extracts of vegetation were used to stimulate hatching of mosquito eggs. Using modifications of rearing media suggested by these authors we found it possible to rear larvae from eggs which were otherwise considered sterile when distilled water alone was used.

Summary

1. Mosquito control in the Greater Winnipeg district during its 25th year again gave satisfaction to residents of that area. The cost was less than 4 cents per capita.
2. The use of DDT in spray and in fog gave good control of larvae and flying mosquitoes, and will be used in 1952. DDT resistant mosquitoes have not been noticed.
3. In tests covering the period 1947–1951, DDT applied in the fall has controlled larval breeding the following spring and summer for a period of 6 weeks up to 6 months following the spring thaw.
4. Chemical tests under the supervision of Mr. B. Berck, of samples from particular test areas showed that there were still substantial amounts of DDT in the water, vegetation and soil 10 months after the DDT was applied.
5. Bioassays using *Aedes aegypti* mosquito larvae in the laboratory following the chemical tests for DDT in water, soil and vegetation, failed to indicate toxic qualities of the DDT residues in the samples taken.

If you have not already purchased a copy of Bulletin #2, "Ground Equipment and Insecticides for Mosquito Control," place your order soon. The information it contains is indispensable to mosquito control workers. Copies of the Bulletin are still available at $2.00 each. Orders should be sent to Mr. C. T. Williamson, Suffolk Co. Mosquito Control Commission, Yaphank, N. Y.

FUTURE OUTLOOK OF MOSQUITO CONTROL IN FLORIDA

JOHN A. MULRENNAN [1] AND V. SAMUEL MINNICH [2]

During the summer of 1951 the State of Florida was confronted by the worst salt marsh mosquito problem in a good many years. Not only were there more mosquitoes than ever, there were more summer tourists than ever. This caused a good deal of consternation, particularly in Chambers of Commerce. The simultaneous advent of mosquitoes and tourists occurred at a time when it was impossible to obtain DDT and BHC in quantities sufficient for even minimum control. As a result, mosquito control directors were subjected to abuse delivered in the press, over the telephone, and at public protest meetings

Full moon tides apparently were the foremost factor in the tremendous production of salt marsh mosquitoes. These tides were higher than normal. They flooded the marshes longer and they occurred regularly from May through October.

In addition to high tides, heavy rainfall, DDT resistant mosquitoes and a shortage of chemicals contributed to the adverse mosquito conditions which prevailed in Florida during the 1951 season.

The trend in mosquito control in Florida is changing. And we think this is a healthy sign. For the past five years emphasis has been on chemical control. Now we are going back to fundamental control: elimination of breeding grounds.

It has been evident in Florida for the past three years that DDT was losing its punch as a larvicide and adulticide. For this reason, several counties, during 1951, bought draglines and began ditching and draining marsh areas.

Volusia, Indian River and Manatee Counties have gotten "fundamental control" projects underway. Others are saving money towards purchase of draglines.

Florida controllers are convinced that chemicals—no matter how lavishly used—will prove unsatisfactory until marshlands have been neutralized by draining and circulation.

The Florida State Board of Health, in November, 1951, recommended a program for long range control after observing that:

a. Counties were spending more money to fight mosquitoes than ever before.
b. The State was contributing $15,000.00 to each County for use, together with County funds, for mosquito control.
c. Practically all of the funds were being spent for chemical control.
and
d. Mosquito control, instead of improving throughout the state, apparently was becoming worse.

The State Board of Health advised Mosquito Districts that the trend toward evermore chemical mosquito control must be stopped. The Board suggested, in addition, that steps be taken toward state encouragement of permanent mosquito control. It recommended passage of legislation whereby the state would contribute to a mosquito control district or Board of County Commissioners assessing a millage for mosquito control, funds equal to 75% of district-raised tax moneys. The Board further recommended that State funds be given only for financing well engineered, permanent mosquito control projects.

In such a plan lies Florida's only hope of ridding itself of its mosquito problem.

The chemical control still practiced so generally in Florida costs millions of dollars. When people demand more of this type of control, they fail to realize that fifty years and $100,000,000.00 from now

[1] Director, Division of Entomology, Fla. State Board of Health, Jacksonville, Fla.
[2] Director, Volusia County Anti-Mosquito District, Daytona Beach, Fla.

there will be just as many mosquitoes as there are today.

This can be predicted: If the State Legislature meeting in 1953 follows the recommendations of the State Board of Health, by 1960 a very marked reduction in salt marsh mosquito population should be evident along the coastal areas of the state.

Perhaps some new, effective and economical weapon for mosquito control will be found. We hope so. But, until it is, the State of Florida once again will employ fundamental control, supplemented by larviciding and adulticiding. Florida mosquito controllers don't want to be caught again uselessly using DDT against DDT resistant salt marsh mosquitoes.

The entire coastal area of Florida is covered by mosquito control districts, broken only in two places—one on the East Coast by Flagler County, and one on the West Coast by Charlotte County. It is believed that, by 1953, these two Counties will have voted to establish districts.

THE MOSQUITO SOURCE REDUCTION PROGRAM OF THE MERCED COUNTY MOSQUITO ABATEMENT DISTRICT

EDGAR A. SMITH

Manager, Merced County Mosquito Abatement District

The Merced County Mosquito Abatement District was organized in 1923 as a 17-square-mile district to do malaria mosquito control in and around the city of Merced. In order to control the pest field mosquitoes (*Aedes dorsalis* and *Aedes nigromaculis*) the district was expanded to 90 square miles in 1940. As a result of a tremendous increase in the acreage of land under irrigation, particularly irrigated pastures, the *Aedes sp.* problem became increasingly severe throughout the county in the period from 1935 through 1945. The acreage of irrigated pasture increased in this same period from 300 acres to 28,000 acres. As a result of this increased mosquito problem combined with the threat of the introduction of mosquito-borne diseases by returning veterans from the tropics and the prospect of financial aid from the proposed California State Subvention program, the district was expanded to a county-wide basis of 1,995 square miles in 1945.

At the present time about 1,400 to 1,500 square miles of the county are under irrigation and hence pose a mosquito problem. At least 70% of the problem results from irrigation water in one way or another. There is some mosquito production in the irrigation facilities such as canals, ditches and drains, but by far the largest source of mosquitoes is in the irrigated fields themselves. As indicated above, irrigated pasture is the most consistent producer of mosquitoes, but any irrigated crop can and does produce mosquitoes when and if water stands long enough (3 to 5 days in mid-summer heat). This would include 250,000 acres of wild pasture much of which is irrigated sporadically by uncontrolled flooding; 100,000 acres of alfalfa; 70,000 acres of barley; 40,000 acres of cotton, and 7,000 acres of rice as well as smaller acreages of tomatoes, beans, corn, sugar beets, orchards and vineyards.

In some cases mosquitoes are produced in irrigated fields as a result of carelessness or ignorance on the part of the farmer. However, in many cases excess water is left standing for a variety of reasons beyond the control of the farmer. This subject has been well covered by Lloyd Myers, who was assigned to Cali-

fornia from the Public Health Service, in a paper on "The Relationship of Agricultural Drainage to Mosquito Control Drainage" to be published in the Proceedings of the California Mosquito Control Association for 1952. In most cases the farmer himself wants to avoid excess standing water on his crops and is also anxious to get rid of it once it is standing, as he knows that it will harm his crops in all cases, except rice.

According to California law the property owner who is producing mosquitoes is legally responsible for maintaining a public nuisance which can be abated by due process of law. California districts have seldom made use of the provisions of this law and then only as a last resort. Three of the policies adopted by the Board of Trustees of the Merced County Mosquito Abatement District in December 1949 illustrate the attitude of the district on this matter and serve to guide its mosquito source reduction program. They are as follows:

I. The primary objective of the District shall be the progressive elimination of mosquito breeding places through education, persuasion and cooperation.

II. Stress will be given to cooperation with individuals and organizations to solve mutual problems involving production of mosquitoes. Particular attention will be paid to water management, irrigation and drainage problems and household and industrial waste disposal.

III. In cases where cost of temporary control is prohibitive and when all means of eliminating the source fail, the District will take the necessary steps to abate the nuisance when such action appears to be in the public interest.

The Merced County Mosquito Abatement District approaches the problem of eliminating or reducing mosquito sources from several different angles.

First is a public relations and education program designed to acquaint the public with the "facts of life" in regard to mosquitoes, with special emphasis on what the individual can do to avoid production of mosquitoes or to correct existing situations leading to mosquito production. This includes a systematic attempt to inform the farmers of the advantages of drainage and to point out the help obtainable in solving drainage problems through the mosquito district and other agencies. The public relations and education program starts with every employee of the District as they are all required to be able to discuss the District's program intelligently with anyone. However, it is the operators and the foremen who do the bulk of the contact work with individual farmers. The subjects of mosquito control and drainage are covered in the annual illustrated talks given to the grammar schools and high schools throughout the county. Special talks on the source reduction program of the District are given to service clubs, farmers' organizations, etc. News releases and feature articles have amply covered the District's work.

Second is the matter of cooperation with other agencies to the mutual advantage of all concerned, including the farmer. A year ago the Mosquito District took the initiative in organizing the Merced County Water Conservation Committee. Membership of this group includes about thirty-five organizations concerned with water problems in the county such as the irrigation districts, canal companies, drainage districts, soil conservation districts, County Health Department, County Road Department, County Planning Commission, U. S. Bureau of Reclamation, California State Department of Fish and Game, Calif. State Department of Public Health, local sportsmen's associations, etc.

The Committee has set up working subcommittees on the following subjects: Water Pollution and Contamination, Watershed Improvement and Low Water Table Problems, Drainage and High Water Table Problems, Irrigation Practices, Flood Control, Water Management for Attracting Ducks, and Public Information. The Mosquito District is vitally interested in all of these problems and has taken an active part in the work of the Committee. I was elected as Chair-

man of the entire Committee for its first year and am now Secretary. Cooperation and understanding among the member agencies has improved considerably in the short time of the existence of the Committee. The working sub-committee on drainage has attempted to coordinate work on drainage being done by the various member organizations. This has greatly facilitated cooperation. The Merced County Mosquito Abatement District has received excellent cooperation on drainage projects from the Merced County Road Department, the Merced Irrigation District and the Soil Conservation District at Los Banos.

Third is the actual performance of the drainage work (at cost or less) as an aid to the individual farmers concerned and as a demonstration for other farmers to see. It would appear to be obvious that any type of drainage which removes standing water from a field or roadside and carries it to a drainage channel or natural stream is of necessity performing a mosquito source reduction function. At any rate this assumption is the basis for the policy and practice of the Merced County Mosquito Abatement District in regard to "permanent" or "eliminative" control in irrigated areas which we prefer to call mosquito source reduction.

The Merced County Mosquito Abatement District is in its third year of a drainage promotion program. At present the District owns and operates a Fordson tractor and ditcher, an Allis Chalmers HD-7 tractor and dozer with two ditchers and a grader and a Link-Belt Dragline with ½ yard bucket. All of this equipment is handled in the same way. Individual farmers or groups of farmers contract with the District to have drainage construction or maintenance work performed. The District enters into such agreements only when such work will eliminate or reduce an actual or potential mosquito hazard as shown by the District records; specifically the inspection treatment record card and the section survey map sheet. These cooperative drainage projects may involve only one farmer or they may involve as many as twenty or more property owners. Most of the projects carried out by the District so far have involved installation of drainage systems in irrigated pastures. These are usually designed to carry off the excess irrigation water at the lower end of the checks to a drainage channel where mosquito larvae can be eaten by fish or can be easily sprayed if necessary. This type of drainage is also highly beneficial to the farmer. The farmer's attitude, after successful completion of a project of this kind, is exemplified by the statement made by Mr. Elmer Murchie, Manager of the Crocker-Huffman Land & Cattle Company of Merced. Mr. Murchie credited the Merced County Mosquito Abatement District's drainage program with three positive benefits to them. (1) Relative absence of mosquitoes in the area with drainage systems making it possible for irrigators to work and cattle to eat unmolested. (2) Increased yield of pasture grass. (3) Consequent increase in the weight of beef cattle.

In addition to contracting with the farmer to do the drainage work at cost, the Mosquito District helps the farmer in other ways. Some of the projects are promoted by the District on its own initiative while others are requested by farmers, but in both cases District personnel perform the "leg-work" necessary to get the interest of all the property owners involved. The District sponsors meetings of such groups and provides free legal and engineering advice. Any surveying necessary is done by the District with no charge. If hand work is needed the District provides a crew of rehabilitation center labor with no charge. If easements are needed the District handles the negotiations. If concessions are needed from other governmental agencies the District makes the arrangements. All in all the Merced County Mosquito Abatement District is making drainage available to the farmers at a very low cost.

This type of drainage program reduces the area requiring spraying in some indi-

vidual pastures by as much as 90%. It means that operators, instead of having to spray entire fields, spray only a few residual drains in the field.

The following case histories of actual cooperative drainage projects performed by the District with the tractor and ditcher are typical of the results obtained so far.

	Pasture	Larviciding Cost for One Season	Cost to District for Drainage	Larviciding Cost Following Season
Case A	1,200 Acres	$1,275	$81	$295
Case B	100 Acres	$ 201	$52	$ 19
Case C	33 Acres	$ 29	$11	$ 0

These projects obviously result in a financial saving to the district, but they also mean increased yield to the farmer and consequently increased good will for the district.

We regard our program as a long range approach and our individual projects as demonstrations of what can be done. We realize that there is more to be done by way of drainage in Merced County than any one organization without unlimited resources could ever hope to do. Any reduction of mosquitoes through drainage so far is infinitesimal compared to what is left to be done, but it is at any rate a step in the right direction. Further accomplishment in any marked degree will depend in large part on the cooperation obtainable from the farmers themselves as well as from other agencies.

SUMMARY: The Merced County Mosquito Abatement District is approaching the problem of reducing mosquito sources in irrigated fields by contracting with the farmers to do the necessary drainage construction and maintenance work at cost; by cooperating with and enlisting the aid of other agencies with mutual problems; and by conducting an educational program to promote the solution of drainage problems by the farmers themselves.

THE CDC PROGRAM RELATED TO WATER RESOURCES DEVELOPMENT[1]

CHRIS A. HANSEN

I. Introduction. Water is a major factor in Western prosperity. To the members of this Association, water also means mosquitoes, and mosquitoes mean disease, discomfort, and economic loss. We are all interested in this national resource and its development for the greatest benefit to the greatest number of people. This afternoon, I want to tell you the reasons why we, in the Communicable Disease Center, are participating in the national water resources development activity, the problems we face, and the program we are conducting.

II. The National Water Resources Development Program. Development of the nation's water resources has been under way since early colonial times, but only during the past forty years has the magnitude of this development become significant. Federal, state, local, and private groups are all participating in this work, but often with widely divergent interests and needs. To coordinate the efforts of all, the President, in 1948, ap-

[1] From the Communicable Disease Center, Public Health Service, Federal Security Agency, Atlanta, Georgia.

pointed a commission to study the problem and to recommend *a water policy for the American people.* This commission (1) formulated a proposal for comprehensive water resources development involving coordinated basin-wide planning for maximum beneficial use of the nation's river systems and their watersheds. The proposed program includes 13 primary elements: (1) watershed management, (2) flood management, (3) water supply, (4) navigation, (5) hydro electric power, (6) irrigation, (7) pollution abatement, (8) drainage, (9) recreation, (10) fish and wildlife, (11) sediment control, (12) salinity control, and (13) insect control.

This comprehensive river basin development program includes large reservoirs, stock and fish ponds, canals, irrigation systems, as well as levees and soil erosion control work. Coordination of the work of all interested agencies and groups is achieved by Inter-Agency River Basin Committees. These committees consist of representatives from Federal and State agencies and include active participation by local organizations and individuals. The Communicable Disease Center works through the Federal Security Agency—Public Health Service member of this group.

III. Necessity for Health Agency Participation. The use of water for irrigation has created public health problems since pre-Biblical times. Increased knowledge and improved techniques of investigation have led to recognition of water-derived insects as factors in this connection. Expanding irrigation development and recent emphasis on water resources activities, particularly in the West, require immediate attention to the public health problems involved.

The occurrence of malaria outbreaks resulting from water impoundments in the southeastern United States is well known. Although malaria is no longer a major public health problem in the United States, I believe that it would be foolhardy to ignore the experience of the past forty years by developing water resources without regard for possible future malaria problems. We do not need the caution of fifteen years ago, but we must not create malaria mosquito breeding areas which could not be controlled if a recurrence of the disease demanded control. *Malaria could come back!*

Encephalitis is a growing problem in this country. Equine encephalomyelitis has occurred in every state of the Union with especial concentration throughout the western and midwestern areas. Major outbreaks of encephalitis have occurred in Missouri and North Dakota. The 1933 St. Louis outbreak exceeded 1600 cases of human encephalitis with 310 deaths. In 1941 more than 1100 human cases with 139 deaths were reported in North Dakota. Smaller epidemics have occurred repeatedly throughout the western states. Many of these outbreaks had no relationship to irrigation, but they were associated with unusual natural mosquito production. The Central Valley of California is an important encephalitis area. There, however, endemic encephalitis became prevalent only after major irrigation projects were established.

Research and investigations during the St. Louis outbreak, and subsequent work by numerous investigators have established the fact that mosquitoes can transmit at least five varieties of encephalitis virus. *Culex tarsalis* mosquitoes, commonly found in irrigated areas of the West, have been incriminated repeatedly as carriers of encephalitis virus.

At the third annual Public Health Service Encephalitis Conference, attended by Public Health Service research workers in the field, together with other outstanding virus encephalitis investigators, the following resolutions were adopted:

1. Encephalitis is a public health problem and the potential public health significance of this disease is fully recognized.
2. Preventive mosquito control is justified and should be continued through intensive cooperative action with other Federal and State agencies concerned with water resources development throughout the nation, the principal justification for this program being the

public health importance of encephalitis and pest mosquitoes.

3. Studies should be undertaken on passive and active immunization procedures in man and animals for the purpose of developing means to aid in the control of epidemic outbreaks of encephalitis. An antiserum should be developed if possible, manufactured, and kept in supply for preventive treatment in times of epidemics of the disease.
4. Serologic and pathologic studies should be continued to improve the diagnosis of the encephalitides in man.
5. Continued epidemiologic and ecologic studies are essential to solve many of the unsolved problems in the realm of encephalitis.

These resolutions emphasize the importance of encephalitis to the public health and stress measures for its prevention and control.

Health and well-being are necessary to our way of life as well as a requirement for maximum productivity by our people. To accomplish this objective, mosquito control and disease prevention must be expanded in the public health program. The national policy for conservation of human, land, and water resources *demands* the prevention and control of insects having a deleterious effect on the public health.

Aside from the health interests, mosquitoes also exert a significant detrimental effect on our economy. Beef, poultry, egg, and milk production are significantly reduced by mosquito annoyance. The Crocker-Hoffman Land & Cattle Company of California reports that animals grazed on pastures with mosquito control gained from 50 to 100 pounds each per year more than cattle grazed on pastures without mosquito control. In order to minimize these economic losses, as well as to protect human health, large sums of money are expended. For example, in the State of California, more than 2 million dollars are spent annually on mosquito control.

IV. Insect Problems of Public Health Significance Resulting from Water Resources Development. The principal insect problems created by water development result largely from poor irrigation practices. Such procedures create pooled areas which damage the soil, decrease productivity, and provide a perfect habitat for mosquitoes.

At the present time, there are more than 21 million acres of irrigated land in the United States, mostly in the western states. A serious mosquito breeding problem exists in much of this area. Planned irrigation development is expected to increase this amount by approximately 10 million acres during the next 25 years. It is most important that mosquito breeding be minimized in these new areas.

Reservoirs and other impoundments often produce tremendous numbers of mosquitoes. However, adequate clearing of the reservoir area before impoundment helps to solve the problem. Similarly, canals and laterals are of negligible importance as mosquito breeding places if adequately constructed, operated, and maintained. Seepage from leaky canals eliminates fertile land from production and at the same time creates an excellent habitat for mosquitoes. In the Farmers Irrigation District near Scottsbluff, Nebraska, over 5,000 of 60,000 acres of good farming land have become mosquito breeding seepage areas, useless for agricultural purposes, as a result of seepage from distribution canals.

V. The CDC Program. The Communicable Disease Center has established a Water Projects Section in its Vector Control and Investigations Branch to direct the Public Health Service program for prevention and control of insect problems of public health importance associated with the water resources development. Dr. Stanton J. Ware, Chief of this Section, has established his headquarters here in Salt Lake City in order to be located more centrally with respect to the principal problem areas.

The CDC objectives for this program are: first, to prevent or minimize the creation of new mosquito problems on

water projects being developed; and second, to aid in the elimination and control of insect problems produced by water developments constructed in the past. Our primary emphasis in the immediate future is to be on prevention, and later, as time permits, we will concentrate on the second objective of eliminative and control work. The Water Projects Section of the Communicable Disease Center will not be in the pest control business in the sense of swatting and spraying mosquitoes, but rather in guiding construction agencies and groups in "building" mosquito prevention into the projects. These measures will be extended also to the operation and maintenance phases of irrigation projects. In existing problem areas, we favor a planned long-range program for eliminating the problem and using supplemental repetitive chemical control measures.

Research, investigations, and demonstrations will be conducted to delineate the problem more clearly and to develop effective preventive and control measures. Research workers at our Mitchell, Nebraska, field station are actively engaged in important ecological studies and evaluation of mosquito problems associated with water development in that area. At Angostura, South Dakota, a demonstration is being conducted in cooperation with the Bureau of Reclamation and the Soil Conservation Service to show that mosquito problems can virtually be eliminated in the construction phases. Studies under way at Bakersfield, California, in cooperation with the Hooper Foundation, are designed to broaden our knowledge of the complex virus encephalitis transmission chain. Other investigations are being conducted jointly with the California State Department of Public Health on specific operational and ecological problems. Similar studies will be increased as the need arises and funds become available.

We believe that public health insect control should be an integral part of state and local health department programs. Accordingly, we are assisting State Health departments in developing insect vector control organizations to deal with insects of public health importance.

A definite program is under way for dissemination of technical insect vector control information to water development agencies and water users, on the need for mosquito prevention in water development programs and eliminative and control procedures for existing projects. This is accomplished by preparation and distribution of such authoritative information as brochures, films, filmstrips, and reports. The brochure "Mosquito Problems and Prevention in Irrigated Areas" has just been released.

Surveys of water projects under consideration are necessary to anticipate problem conditions during the planning stage and to outline the necessary preventive measures. We will participate in this work by supplementing, where necessary, the State Health department activities. We are now engaged in evaluating and reporting on the insect problem associated with basin-wide developments planned by various Federal, State and local agencies in the lower Mississippi, Northeast, Pacific Northwest, and Missouri River Basins. This is a part of Federal Inter-Agency River Basin Committee's plan for coordinating the interests of all concerned.

Proper planning will assure the inclusion of mosquito preventive measures in future water resources development activities. We are responsible for coordinating the vector control work of the Public Health Service in these areas. To accomplish these many objectives, we will need to train more professional and technical personnel to carry on the proposed vector control work.

Local communities will be assisted, through the State Health departments, in the organization of mosquito abatement districts in areas suffering from the plague of mosquitoes resulting from water resources development. Technical assistance is available also to existing mosquito abatement districts in similar areas.

Excellent work is now being done by mosquito abatement districts, but that

work covers only a small percentage of the total problem. Scores of additional districts are needed *now,* not only in the West but also in the rice-producing areas of the South, and in coastal problem areas.

VI. Summary. Our program is concerned with the insect problems of public health importance associated with the National Water Resources Development Program. We have two basic objectives, (1) to prevent these insect problems on water projects being developed, and (2) to promote the elimination or control of the problems on existing projects. The cooperation of the constructing agencies, the water users, the agricultural and health agencies, the mosquito abatement districts, and recreational interests will be needed to accomplish these objectives. Many additional mosquito abatement districts need to be organized now to cope with the existing mosquito problems in irrigated areas of the United States—the greatest need is in the West and the rice-growing areas of the South and Southwest. The Water Projects Section will carry out a program of:

1. Delineating the problem by research and investigations and developing effective preventive and control measures.
2. Assisting the State Health departments in developing organizations to deal with insects of public health importance.
3. Disseminating information to water development agencies and water users on the need for insect control measures on existing projects.
4. Promoting mosquito abatement districts in areas plagued by mosquitoes resulting from water resources development.
5. Preparing surveys of projects under development to anticipate problem conditions.
6. Planning to assure the inclusion of preventive measures in future water resources development activities.
7. Coordinating vector control work of the Public Health Service in water resources development areas.
8. Training personnel to carry on vector control work in the areas under consideration.

Reference

1. 1950. U. S. President's Water Resources Policy Commission. Vol. 1: A Water Policy for the American People, U. S. Government Printing Office, Washington, D. C., 445 pages.

PHOTOGRAPHS TAKEN AT THE AMERICAN MOSQUITO CONTROL ASSOCIATION ANNUAL MEETING AT SALT LAKE CITY, UTAH, MARCH 24 TO 27, 1952. These pictures are available through the Western Photo and Science Service, P. O. Box 411, Berkeley, California. 8 x 10 glossy prints are $1.00 each. 1. AMCA Field Tour group picture at Copper Club, Magna, Utah. 2. Kennecott open pit copper mine at Bingham, Utah. 3. Group in lobby (Stutz, L. Smith, Rees, Hirst, Mulrennan, R. F. Peters, Lindquist, Carpenter, Clark, Stage, Dorer, Gray and Twinn. 4. California Group. 5. Dr. Bradley and Chris Hansen. 6. AMCA President and Past-President; Dr. Twinn and Dr. Rees at field equipment demonstrations. 7. Dr. Collins and Dr. Bradley. 8. Mulhern congratulating Raley on his new job as Executive-Secretary of the AMCA with Dr. Rees looking on. 9. President Henderson, Past President Smith and V.P. Bob Peters of the California Mosquito Control Association and their exhibit. 10. Field demonstrations of fog machines at Salt Lake M. A. D. 11. U.S.D.A. personnel at field demonstrations: Husman, Bishop, Lindquist, Gjullin, Hoffman, Stage. 12. Husman demonstrating mist sprayer. 13. T. D. Mulhern and AMCA gift clock (2 poses at Fresno home). 14. Mr. and Mrs. T. D. Mulhern and AMCA gift clock (2). 15. Demonstration of TIFA (Steinrock and Williams—2 poses). 16. TIFA exhibit booth (Schoenfeld, Steinrock, Henderson and Williams). 17. Lawrence Aero-Mist demonstration (2). 18. Weber Co. MAD Butane Fog Machine (2).

THE DIVERSIFIED PROGRAM PREREQUISITE TO EFFECTIVE MOSQUITO CONTROL ON CAPE COD

BERTRAM I. GERRY[1] AND OSCAR W. DOANE, JR.[2]

Some conception of the extent and nature of the mosquito control operations conducted in Barnstable County on Cape Cod may be derived from a relatively small amount of pertinent statistical data pertaining to the area. Since the Cape is a highly developed summer recreational center, adequate control of the mosquito nuisance has a definite bearing upon its economy. The 1950 census showed a native population of 46,381 or 117 persons per square mile; and a summer population of 260,000 or 660 persons per square mile, 82% of whom were visitors on summer vacation. Reasonable protection of these visitors from the ever threatening mosquito nuisance requires a comprehensive control program, which will blanket the entire county comprising a land area of 394 square miles. Using the outstanding physical characteristics of the terrain as a basis, the program may be subdivided as follows: (1) salt marsh breeding, the control of which constitutes the major concern of the project because it involves 1/12 of the total county area and includes, also, the maintenance of 1,500 miles of ditching; (2) the control of 1,200 fresh water swamps with a total area of 4 square miles; and (3) similar problems associated with the 170 great ponds which range in area from 10 to 650 acres, plus those of numerous smaller bodies of water including many permanent brackish pools located along the shore.

On Cape Cod, the salt marsh mosquito (*Aedes sollicitans*) represents the principal nuisance pest. Ditching of the 33 square miles of salt marsh has proved to be the most economical and most effective control method, and has been utilized wherever the soil is of a consistency to withstand tidal erosion. These ditches, which are ordinarily 10 inches wide and 24 inches deep, afford a rapid run-off of tidal water which, if retained on the marsh, would furnish ideal conditions for prolific mosquito breeding. They function, also, as channels through which minnows migrate to the upper reaches of the marsh in search of mosquito larvae upon which they feed. On sandy marshes where ditches are impractical, because of their rapid obliteration by erosive tides, prehatch treatments have been substituted with considerable success. For example, on May 17, 1950, a 4-acre marsh, located at the extreme end of an extensive sandy peninsula known as Nauset beach, was treated with a wet mist applied with a "Tifa" fogging unit at the rate of 1 pound of DDT per acre. The larvicide used in this operation contained 10 gallons of Xylene, 140 gallons of No. 2 fuel oil, and 40 pounds of DDT (technical grade). Periodic observations, after treatment, indicated that no mosquito larvae developed on this marsh during 1950 although flooding reoccurred. Similar observations made during 1951 showed that this prehatch treatment continued effective until August when a thinly scattered larval population became evident.

A second type of unditched salt marsh, under constant surveillance, is the relatively high sandy marsh usually built up along the water's edge, and as a consequence, receives tidal water only at times when a high tide is backed by strong winds. On August 6, 1951, a 25-acre marsh of this type, located on the Nauset peninsula, was examined and found to be dry and hard with no evidence of mosquito breeding. However, a few hours later the marsh was inundated by an unusually high tide. On August 13, adults were numerous in this area and the stand-

[1] Massachusetts Reclamation Board.
[2] Cape Cod Mosquito Control Project.

FIG. 1. Typical Cape Cod inlet with mosquito control ditching.

ing water on the marsh contained large quantities of larvae and pupae. The area was treated immediately with a DDT-oil spray applied with a 150 gallon hydraulic spray unit mounted on a power wagon especially equipped for salt marsh operations. The spray contained 10 gallons of Xylene, 140 gallons of No. 2 fuel oil, and 50 pounds of DDT (technical grade). From two loads, a total of 246 gallons of fuel oil and 82 pounds of DDT were applied, thus providing oil at the rate of approximately 10 gallons per acre and DDT at the rate of 3 pounds per acre. After treatment, the marsh was examined periodically, and although flooding recurred, no larvae appeared during the remainder of the 1951 mosquito breeding season. The unusually heavy dosage of DDT was decided upon because of the fact that some of the spray was being applied directly to water surfaces.

One of our most aggravating problems is the control of mosquito breeding in cedar swamps, which have been practically impenetrable since the hurricane of 1938, except for short periods during the winter months when the standing water is coated with ice. During the early months of 1951, while these swamps were frozen over, a series of 4 adjoining swamps, with a total area of 10 acres, were subjected to prehatch treatment. By utilizing knapsack dusters, 50% wettable was applied to the ice at the rate of 1 pound of DDT per acre. In order to attain uniform distribution and eliminate any substantial loss by drifting, the dust

was applied during a period when wind velocity was approximately 5 miles per hour. As a result of this treatment, no mosquito nuisance occurred in these swamps during the 1951 breeding season.

Another problem of long standing is the control of *Mansonia perturbans* breeding in those ponds and lakes which support an abundant cattail growth. In 1947, the experimental treatment consisted of an application of residual DDT to vegetation located in the immediate vicinity of the water area. In spite of this treatment of the probable mosquito resting places, adults in numbers sufficient to create a nuisance penetrated the barrier. As a result, it was necessary to resort to fogging as a means of alleviating this nuisance. In more recent years, the host plant (cat tail) has been sprayed during the first week of June or before the new growth attains a height of 10 inches above the water surface. The residual spray of 50% wettable DDT is applied at the rate of 1 pound of DDT per acre by means of a 150 gallon hydraulic spray unit equipped with a 500 foot extension hose. The cat tail field is divided into strips approximately 50 feet wide and each strip treated as an individual unit in order to facilitate a more even distribution of the insecticide. In treating, the extension hose is dragged out along the edge of the strip as spraying proceeds from the proximal to the

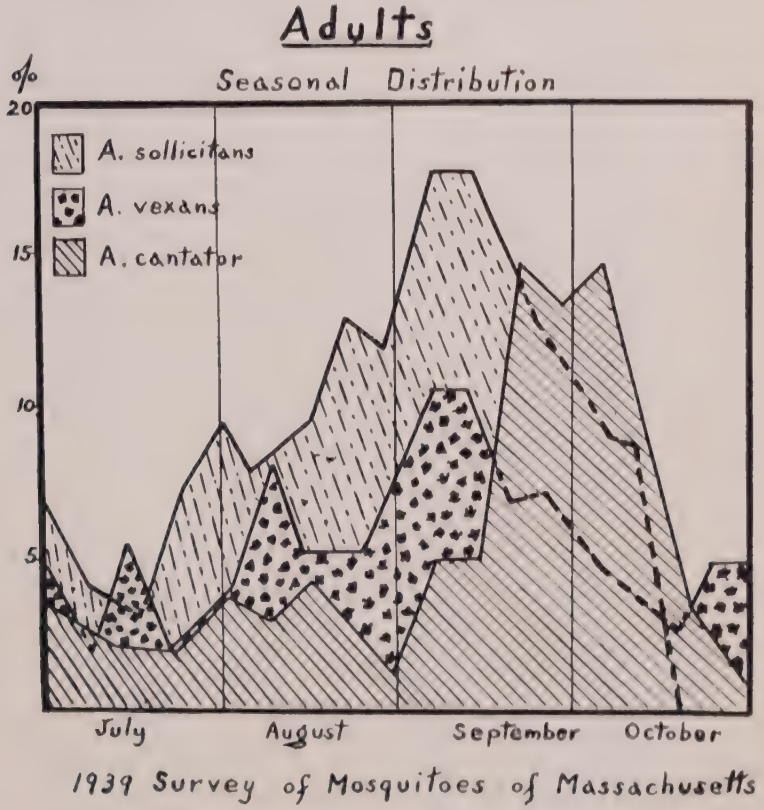

FIG. 2. Chart showing predominating species of mosquitoes on Cape Cod and their relative peaks of production

distal end. This method has provided effective control of *Mansonia perturbans* in our cattail fields, a fact well substantiated by voluntary testimonials from individuals who reside in the vicinity of the *Mansonia* breeding areas.

During the summer of 1951, the Cape Cod Mosquito Control Project resorted to a rather extensive fogging and aeroplane spraying program. These were emergency measures adopted to meet critical mosquito breeding conditions. Our experience with adulticides was rather disappointing but did serve to strengthen our confidence in ground spraying equipment as a supplement to the basic drainage method.

MOSQUITO CONTROL: EXTENSIVE VERSUS INTENSIVE TECHNIQUES

LCDR JOHN M. HIRST, MSC, USN

Officer in Charge, U. S. Navy Malaria and Mosquito Control Unit No. 1

Mosquito control techniques are in a constant state of change. Species distribution, topography, political structure, individuality of operators and many other conditions are predetermining factors in the mechanics of any mosquito control program. But it has been observed that the gradual change is from an extensive to an intensive technique. By definition, we understand the term *Extensive Technique* to mean the working of a large area with a limited number of treatments as opposed to the term *Intensive Technique* in which small areas are worked or treated on a more frequent schedule.

The rapid development of chemical controls resulted in an immediate attempt by many operators to treat large breeding areas. Numerous varieties of equipment mounted on vehicles, tractors, boats, trailers and airplanes came into use. Improved insecticides appeared rapidly and have continued to out distance the modifications of large scale dispersal equipment and operators' abilities. Operational costs were compared with permanent control expenses and found to be desirable to tax paying constituents. In one county, as in many others, all permanent maintenance of drainage was discontinued and all plans for future ditching, drainage and fill were cancelled. Initial costs were less than $1.00 per taxable person per year and controls were as much as 95 percent efficient. Everything favorable to *extensive techniques* was being experienced. Even inaccurate results collected by inadequate formulae and interpreted incorrectly were published, accepted and credited. Many insecticide producers were and still are unable to meet demands. Equipment manufacturers found a ready market for anything that could be adapted to the immediate need of the mosquito control operator and at almost any price. Laborers, supervisors and directors were producing better results than ever before. It was a simple matter to extend the areas controlled and limit or omit mosquito control sanitation programs. One small county bought seven airplanes. Another county bought four airplanes and declared openly that more planes would be purchased if found necessary. In fact, the only limitation on the extent of the control area seemed to be the amount of money available. Since this amount had been predicated on experienced costs for permanent control measures, considerable funds were available.

Only those mosquito control organizations which were stabilized by long experience and were fortunate in having highly trained personnel available could

stand the pressure of these most radical changes. New mosquito districts began to form and to declare their abilities to eradicate or eliminate the mosquito hazard.

These preliminary events are responsible for the present day movement or change which has a great potential worthy of note. It is observed that taxpaying constituents are becoming more limiting to the amount of money "sprayed away." Costs of this extensive technique have increased until $4.00 to $10.00 per taxable head per year are being reported. Mosquito control workers are realizing their folly in the omission of permanent control projects. In some areas Mosquito Districts require a certain percentage of all funds to be directed to permanent measures. The U. S. Soil Conservation Service has shown that the prolific breeding of certain areas is greatly reduced by reclamation projects. Lake or swamp maintenance is found to be profitable in the production of game fish with the simultaneous reduction of mosquito breeding.

A ten-acre "borrow pit" was easily and inexpensively modified to produce several hundred pounds of fish monthly. Its importance as a breeding area was greatly reduced when "bank sanitation" and water fertilization was instituted. The cost of this new technique is much less than the cost of chemical control prior to reclamation. In addition, the water table of the adjacent area is retained and agriculture does not suffer which frequently resulted from excessive drainage. Even in areas where mosquito control continues to be necessary subsequent to reclamation, greater ease of treatment is experienced and more efficient results are produced.

The worst condition which has followed this extensive technique is an observed reduction in operator proficiency. This may be due in part to confusion brought on by the great variety of chemicals and machines. The best analyses of reports from very reliable testing and research centers prove difficult to interpret in terms of operational requirements. These conflicting data are almost impossible of assimilation by the practically trained field men. Adequate sources of scientific interpretation into field mechanics and directions are lacking. Dangers to operating personnel as well as possible harm and damage to persons and wildlife in treated areas are increasing daily. As a result more stringent controls by responsible agencies have already made their appearance.

And so we can see the movement to an *intensive technique* has been along lines of least resistance. Where knowledge, money and equipment are scarce, the intensive technique was to be expected. But is this the answer? Surely, in certain states where the extensive technique never was developed, but permanent controls were augmented with good larviciding procedures, the most stable mosquito control efficiency is maintained.

Where airplane spraying can be accomplished at a cost of $.25 to $.35 per acre including the insecticide, it is still an excellent tool. Reports from many districts show the cost of aerial applications have risen to rates from $.55 to $.75 per acre. This tool for extensive insecticide dispersal is good but is self-limiting. Aerial insecticide dispersal by present Navy technique costs less than $.25 per acre but this is almost impossible outside the Military. Therefore, the airplane which looked so good as a tool for our mosquito control workers is rapidly losing its importance.

Large pieces of ground equipment are available from many manufacturers. Unfortunately, these companies are not able to keep up with the developments of the chemist. So today we have many chemicals of great value but no means for accurate and efficient dispersal. Numerous scientific tests of these large machines are biased in their results or the machine is still not so good as its operator. Many operators are heard to say "I bought that machine for its psychological effect, I doubt if it kills anything." And so we are warned, that the "psychological effect"

will not remain efficient and we must, sooner than we think, control mosquitoes.

In some reports it seems apparent that the operator is desperate. His disrespect for complaints is a sure sign of coming failure. Too often some operators point with pride at the low incidence of diseases related to insect vectors as evidence of his efficiency. Or as a last resort the operator procures a machine with a thunderous roaring engine to prove to his constituents "you heard the crew spraying last night."

What may be our plan for 1952?

1. *Don't experiment in the field.* There are too many "researchers" now. Use what you know to be good which is in keeping with your means. Accept what has been proven by responsible persons who are devoted to your problems through their affiliation with responsible agencies. If five percent is good, seven and one half percent may be no better but the addition of a synergist may be the answer. But let someone else do the experimenting.
2. *Survey your area again.* Even if we have been working in the same area for many years we must recognize the changing environment. Excellent controls in a familiar area were completely upset last year by the sudden appearance of *Psorophora discolor*. The broods were so great that they constituted 84 percent of the mosquito index for the year. They were found to be breeding in an area under construction which, due to unusual weather, became a perfect breeding medium. Alert surveying might have allowed the operator an opportunity to avoid this upset or establish a more efficient control.
3. *Study your profession.* For your personal safety, the protection of the health of others, the preservation of wildlife, scientific mosquito control requires constant study. Oiling of standing water may have been satisfactory and was accomplished by the untrained. But the use of chemical controls must be under the careful supervision of the specialist.
4. *Don't put all your eggs in one basket.* One county goes bankrupt because it owns so many spray planes. Another fails because it expects chemical control to be the only answer. Where successful programs are in operation, about 55 percent of all labor and money is expended for permanent control measures. Larviciding and adulticiding are coordinated to reduce the mosquito population from areas which continue to produce. But these good operators are sure that a fill is used where a fill should be, drainage is planned where drainage can be accomplished, and flushing is developed where it can be dependable. And thus resistance is being prevented.
5. Finally, *don't give up.* Some mosquito control commissioners have been swayed to reduce operations on the basis that "you can't kill them any more." Excellent results are being produced by the alert and ambitious mosquito control worker. Those who are willing to accept defeat are not prepared to do mosquito control.

SUMMARY

The "magic mile" and the "barrier" technique have never been completely successful. The limitation of the control area is determined mainly by the mosquito but the limitation of the area controlled is dependent on Man. Extensive techniques are required in some locations but should be coordinated with intensive techniques. "If an ounce is good a pound is better," can not be a rule for insect control workers. Where an operator knows his problem, intensive techniques may more likely succeed.

THE APPLICATION OF LARVICIDE BY AIRPLANE FOR CONTROL OF BLACKFLIES (SIMULIIDAE)

D. L. COLLINS,[1] B. V. TRAVIS [2] and HUGO JAMNBACK [1]

A previous paper by the same authors (Travis *et al,* 1951) described blackfly control operations which included strip spraying by helicopter to eliminate blackfly larvae from the streams in a portion of the Town of Webb, in the northern part of Herkimer County, New York. The method consisted of spraying parallel strips one swath wide, one-fourth of a mile apart across an area of almost 40 square miles. It was thought that the maneuverability of the helicopter at slow speeds would make it especially suitable for this type of work, but it was found unnecessary to take advantage of this feature.

The results were considered sufficiently promising to warrant the inclusion of aerial larvicide treatments in the regular control program without the addition of the helicopter fogging, which had been a feature of the original large scale control effort.

In 1951, therefore, the aerial fogging was omitted, and the aerial larviciding was done by fixed-wing planes. Some larviciding was also done with DDT-impregnated plaster blocks in a tract adjacent to the one which was treated from the air.

Procedure. The planned operations pattern was for two Piper Cubs to fly adjacent parallel 100-foot swaths ⅛ mile apart. Each plane had 2 spray nozzles calibrated to deliver 0.35 gallon per minute at 60 pounds tank pressure. It was estimated that at 60 miles per hour a dosage of 0.1 pound of DDT (½ pint of solution) per *swath* acre would be delivered. One acre 100 feet wide would be 435.6 feet long. There would be 12.12 such acres in a swath a mile long.

At ⅛ mile apart beginning at one side of the plot and finishing on the side opposite there would be 9 such swaths in a plot 1 mile square. Thus, 9 swaths of 12.12 acres each would be 109.08 acres in each square mile actually covered by spray. This means that on an over-all "square acreage" basis (the usual method for calculating spray dosages over water for mosquito control), the dosage would be 109.08 × .1 or 10.9 pounds DDT per square mile or 0.017 lb. per acre. This difference between the dosage per acre on a regional basis and the dosage per swath acre should be kept in mind. In this paper, unless otherwise noted, the references are to *dosage per swath acre.*

The spray, as in 1950, consisted of 20% DDT, 20% fuel oil and 60% auxiliary solvent (Sovacide F). The entire acreage, comprising some 90 to 100 square miles, required approximately thirteen 54-gallon drums of solution and 1260 pounds of DDT. Calculating from these figures an average dosage of .019 lb. of DDT per acre was applied, a figure which is surprisingly close to the .017 lb. per acre calculated as the theoretical dosage on a regional basis.

Results: Effects on larvae in individual streams. Calculation of the actual dosages applied is complicated by the fact that through an error in mixing, one sector, a section about 16 miles long and 4 miles wide, was covered first at the rate of only .017 lb. *per swath acre,* using a 3.2% DDT solution with the usual swath pattern. After this error was discovered, the section was re-sprayed with full strength solution (20% DDT). On this second coverage the pilot did not fly the swath pattern, but rather attempted to cover selected streams in order to save material and flying time. Results of this method indicate that a combination of a regular pattern in some sections with topical

[1] Office of State Entomologist, N. Y. State Science Service, Albany, N. Y.
[2] Department of Entomology, Cornell University, Ithaca, N. Y.

treatment in others may prove to be the best procedure.

Even the lighter dosage apparently caused a substantial reduction in larval population, estimated at 72%. After the supplementary treatment the populations in all but three streams were reduced virtually to zero (Table 1).

TABLE 1.—Reduction in numbers of blackfly larvae in streams treated by aircraft with DDT. (Treated at the rate of 0.017 lb. [1st spray] and partially at the rate of 0.1 lb. [2nd spray] per swath acre).

Stream	Blackfly larval populations * Before treatment	After 1st spray	After 2nd spray
2nd Okara outlet	70	30	0
Indian Brook North Branch	2000	150	0
Ind. Brook	1000	rare	0
Safford Pond outlet	70	0	0
1st Little Safford inlet	150	50	30
2nd Little Safford inlet	150	50	30
3rd Lake Creek	20	rare	0
Pole OF #38 stream	50	20	0
Pole CYNY #861 stream	30	10	–
Old Forge Dam	100	30	0
1st stream south of Indian Brook	400	20	200

* Units used are number of larvae per 10 attachment units, which were generally grass blades, or stones 4 to 8 inches in diameter.

Of the three streams showing poor control the "first stream south of Indian Brook" was the same stream that showed poor control in 1950 (Travis *et al*, 1950). This stream and the other two ("Little Safford Inlets") were small streams, hardly more than 2 feet wide, and contained many dead leaves. The explanation for the poor control in these three streams is still uncertain. The most obvious explanation is that they were so small that they were missed, or had insufficient surface exposed to the spray swath because of overhanging vegetation.

Several streams that had not been seen before treatment were examined after the spraying. In one of these, Lily-pad Pond Outlet, living larvae were numerous, but there were also many thousands of dead larvae which had been washed downstream and were caught by their silken threads, virtually strained out by fallen spruce trees the branches of which were partly submerged. It was noticed that most of the larvae which survived were nearly ready to pupate.

The poor kill in this stream may have been due to the fact that mature larvae are more resistant to the insecticide, as suggested by Gjullin, Cross and Applewhite (1950).

Observations in one of the small (width 3 to 4 ft.) streams in the area treated with 0.017 lb. of DDT per swath acre showed that the maximum effect was achieved in the comparatively short period of time of 1½ hours, although this extremely light dosage did not result in complete eradication of the larvae. Five-minute samples were taken at half-hour intervals with a square-foot sampler (see Travis, *et al*, 1951 for technique), beginning a half hour before treatment. At the time of the second sample the plane was laying down a spray swath about 300 yards upstream from the sample point. The figures obtained in these successive samples are given in Table 2.

TABLE 2.—Five-minute samples taken from a stream treated by aircraft (1951). (Treated at the rate of 0.017 lb. DDT per acre.)

Time	Number of Blackfly larvae
12:35 p. m.	2
1:05 " *	–
1:35 "	7
2:05 "	68
2:35 "	108
3:05 "	47
3:35 "	30
4:05 "	20
4:35 "	7
5:05 "	1

* Plane passed about 800 feet upstream at 1:05 p.m. The spray could be seen and smelled.

It is significant that the numbers of arthropods other than blackfly larvae carried downstream during this period of observation did not increase, the average number both before and after treatment being less than one per sample.

Other observations also indicated that no serious reduction in populations of arthropods other than blackfly larvae resulted from the treatments described. These observations will be presented in a later paper.

Results as indicated by collections of adult blackflies. The ultimate objective of the treatments was, of course, the abatement of the nuisance of the biting blackflies, and the degree of this abatement is the real measure of the success of the treatments.

The figures on relative numbers of annoying adults were obtained by estimating the numbers flying about the observer at the end of a 10-minute observation period. The accuracy of these estimates was checked from time to time by net counts. In an effort to obtain a more accurate and detailed picture of the population trends of these blackflies, a total of 309 observations were made during the blackfly season in 1951. In the corresponding period in 1950, 172 observations were made. These observations were made at widely separated points inside and outside of the control area. Observations made in June are summarized in Table 3 .

TABLE 3.—Occurrence of high and low counts of blackfly adults in treated and untreated areas in June 1951.

Numbers of flies	No. of observations at indicated frequency	
	In treated area	In untreated area
Less than 1	45	28
1 – 5	5	15
6 – 10	0	9
11 – 20	2	11
20 +	0	2
Totals	52	65

It should be noted that the number of annoying blackflies inside of the control area includes observations in marginal control areas where control was sometimes relatively poor. Annoying blackflies were rare in the village of Old Forge during the 1951 blackfly season.

Literature Cited

TRAVIS, B. V., D. L. COLLINS, G. DE FOLIART AND H. JAMNBACK. 1951. Strip Spraying by Helicopter to Control Blackfly Larvae. *Mosquito News* 11(2):95–98.

THE IMPORTANCE OF CORRECT TIMING OF LARVAL TREATMENTS TO CONTROL SPECIFIC BLACKFLIES (SIMULIIDAE)

HUGO JAMNBACK

New York State Science Service
State Education Department, Albany, N. Y.

In the central Adirondacks, blackflies are annoying to man from mid-May until early July. Until the advent of DDT, no satisfactory method of controlling these pests was known. In 1948, a blackfly control program was initiated in the Town of Webb in the central Adirondacks. DDT fog dispersed by both helicopter and ground fogging equipment proved to be an effective, although expensive, method of killing adult blackflies.

In 1949, a larval control program was undertaken in an effort to develop less expensive methods of control. DDT-impregnated plaster of paris blocks, placed in streams containing blackfly larvae, when properly used gave adequate control. Dosages of 0.0005 to 0.001 p.p.m. for 24 hours reduced larval blackfly populations almost 100% and had very little effect on the populations of other aquatic arthropods.

In 1950, DDT in oil solution was applied by aircraft, at the rate of 0.1 pound

per swath acre over the more inaccessible areas. Including both blocks and airplane spray, streams within an area of over 100 square miles were treated. (Travis, Collins, de Foliart and Jamnback, 1951).

In spite of early season fogging and the larval control measures mentioned in the paper cited previously, it was noted that in the latter part of the season of 1950 there was an increase of blackfly annoyance and that the species were chiefly different from those that were prevalent earlier. As with other groups of insects, the biologies of the different species of blackflies vary greatly. Since there are several annoying species of blackflies in the local streams it was thus demonstrated that control measures must be directed against particular species, a fact that hitherto had not been emphasized.

In the Adirondack region of New York more than 17 species of blackflies have been found in the course of these studies. Only three of these species are annoying to man in this region. One, *Prosimulium hirtipes* Fries, overwinters in the larval stage, pupating in late April and early May. It is believed that the other two annoying species, *Simulium venustum* Say and *Simulium tuberosum* Lundberg, overwinter in the egg stage, the larvae appearing in late May.

Larval control in 1949 and 1950 was based on a single treatment applied in late April, by which the larvae of *P. hirtipes* were almost entirely eliminated from treated streams. However, the larvae of *S. tuberosum* and *S. venustum* appeared in these streams between 2 and 4 weeks after treatment for *hirtipes* larvae. Studies of the species of annoying adults collected inside of the control area in 1950 revealed that *venustum* and *tuberosum* were present, sometimes in fairly large numbers, and constituted the predominant late-season annoying species. It thus appeared that suppression of the developing first generation *venustum* and *tuberosum* larvae would be necessary to develop an effective blackfly control program.

With this information in mind, two experimental treatments with plaster blocks were applied to nine streams during the 1951 season to determine whether or not they could be kept free of larvae of all annoying species of blackflies for the entire blackfly season. The Town of Webb crews also treated many streams a second time as a part of the routine control program. The first treatment was applied in late April to eliminate *P. hirtipes* larvae; the second, between May 27 and June 5 to eliminate first generation *S. venustum* and *S. tuberosum* larvae. It was found that streams so treated remained free of larvae of the annoying species until June 20 or later.

Since annoying adults are present in such diminished numbers after the beginning of July, it is concluded that the larvae found in streams in late June or after do not develop into a nuisance generation. The reasons for this are not entirely clear, but data gathered in 1950 and 1951 suggest that it may be because only the first of the several generations of *venustum* and *tuberosum* are attracted to man, at least in this area.

By treating streams twice, at the times, respectively, when the two annoying groups of blackflies are in the highly susceptible larval stage, the number of annoying adults emerging from streams inside of the control area can be reduced almost to zero. On the other hand, stream treatment to reduce the populations of blackfly larvae in general, without knowledge of the species involved, will generally result in much less effective control.

Literature Cited

TRAVIS, B. V., D. L. COLLINS, G. DE FOLIART AND H. JAMNBACK. 1951. Strip Spraying by Helicopter to Control Blackfly Larvae. *Mosquito News* 11(2):95–98.

THE PATH OF LEAST RESISTANCE IN CALIFORNIA MOSQUITO CONTROL

RICHARD F. PETERS

Chief, Bureau of Vector Control
California State Department of Health

While the title of this paper has been inspired by that dilemma in insect control referred to as "resistance," I must confess in the beginning that I am using the word "resistance" and the phrase "the path of least resistance" with a somewhat different connotation. Actually, the resistance which we refer to in the sense of the adaptation or tolerance of insects to insecticides has in large part come about through the recent emphasis in control having followed the path of least resistance.

On the basis of early evidence, the chlorinated hydrocarbons with their residual characteristics certainly held spectacular prospects for keeping economic, noxious, and vector arthropods at levels of little or no consequence. For a limited period of time this interloping miracle did seem possible, leading even some of the most conservative environmentalists to wonder if the age-proven fundamentals of basic sanitation and clean cultural practices had gone out. However, it did not take long for arthropods, the product of millions of years of evolution, to adjust and to revert with a seeming vengeance. That nearly every mosquito control agency climbed aboard the chlorinated hydrocarbon bandwagon is not surprising for the degree of public reaction in favor of the program did provide the individual program administrator with the most vital reward of any public service effort—public support. Such a show of support in turn provided encouragement to this kind of public service. Regretfully, this desire to provide the public with what it, from outward appearances, wanted, has to a great degree caused irrationality with respect to program balance, at least temporarily. This accentuated insecticidal approach to mosquito control, while economical in a relative sense, contented itself all too completely with merely treating the environment to reduce mosquitoes rather than organizing the environment to prevent mosquitoes from occurring. While going along on this expedient program emphasis, mosquito control agencies have been accepting a secondary place in assisting to plan the environment for the long range economic good of the public.

Why has mosquito control been content to accept a secondary place in planning and organizing the environment with respect to water and its use? What other local interest in water besides mosquito control has so impartial and generally beneficial a relationship to the various other water use interests? Mosquito control is without question the most neutral medium which has within its power, through agricultural, industrial and community acceptance on the basis of compatibility, the opportunity for leadership on the rather tense and touchy subject of water where the great diversity of concern has led to anything but true cooperation. Water use with its underlying significance to domestic, agricultural, industrial, conservational, recreational and other interests certainly deserves more cooperative planning than it has received to date. Does not mosquito control possess the unique attribute which would allow for leadership in bringing about this cooperation? If mosquito control were to accept this potentiality for leadership in promoting cooperation in local water use, how may it prepare itself?

It would seem the first task would be to take inventory of its present and future ability to assume such a task. Then, if mosquito control is to accept this responsibility and the challenge contained, a long range course of action would, in most

cases, have to be developed in full recognition that:

1. Mosquito control personnel owe it to themselves and the public that they thoroughly understand the other interests concerned with water.
2. Eventual results will not come about by mosquito control working alone, but rather will most likely come through development of a generous spirit of cooperation among the various interests in water.
3. Such ends are not likely to be prompted by statute or enforcement methods but rather by applied education in its many ramifications as the very foundation of realizing this long range goal.
4. The personnel of mosquito control must be of such a caliber and selected with such care as to assure that each person can accomplish public education with each contact, as well as provide other water interests with the reliability of the action taken toward meeting the overall best use of water. This can only mean the gradual accentuation of professional services within the key functions of the mosquito control program.
5. The need for accurate record keeping of both operational and entomological types, based upon a system of mapping that is coherent to the various water use interests, is plainly obvious.
6. The emphasis of the program conducted in mosquito control must provide an underlying character about it which is going to promote efficient and as nearly total use of water as is possible. This can only mean an emphasis in mosquito control toward progressive reduction of mosquito sources, or the confining of water in such a way as to make it easily treated, or unsuitable to mosquito propagation.
7. Lastly, it would become the responsibility of mosquito control to pursue the scientific investigation of its unknowns in order that the courses of action taken will ultimately be based upon known fact consistent with a well organized environment.

If this inventory were to be accepted and the mosquito control program were to be dedicated toward assuming initiative and eventual leadership in preparing the environment for efficient all around water use, it follows that the direction of mosquito control must be toward the general field of preventive practices. The two avenues of realizing mosquito prevention would seem to lie in the development of better and more complete information on mosquito ecology and the devising of ways and means for mosquito source reduction.

We should seek to follow the late Professor W. B. Herms' advice of "know well the insect" in order that we may be assured of our control methods. Considerable investigational work is under way, aimed at providing both timing and placing of control effort where it will do the most good. Our definition of the ecological approach in investigations includes a comprehension of where and when naturalistic control, chemical control, crop management practices, engineering methods, and other potential new approaches to mosquito control can and should be used. By systematically organizing evidence which characterizes the individual mosquito species of concern we are confident that the studies and demonstrations developed through a long range investigational program will answer many of the unknowns to mosquito control. Through providing answers to the unknowns and with mosquito control accepting leadership in positively working toward organizing the environment for cooperation in water use, there exists a promising prospect for lessening the mosquito potential in the foreseeable future. As a result of such a combined program taking effect, we could certainly then be going along a path of least resistance.

REPORT OF LARGE SCALE PRE-HATCH DUSTING FOR *AEDES VEXANS* CONTROL IN THE PASSAIC RIVER VALLEY DURING 1950 AND 1951

ROBERT L. VANNOTE

Director and Consultant, Passaic Valley Dredging Program, Essex and Morris County Mosquito Extermination Commissions

Introduction. In the upper Passaic Valley some 20,000 acres of lowland border the channels of the Passaic, Pompton, Rockaway and Whippany Rivers. Summer floods, inundating the lowlands, result in tremendous broods of *Aedes vexans* and *Aedes trivittatus* whose flight range extends over an area populated by a million and a quarter inhabitants.

Although extensive channel improvements and lateral drainage work is in progress, temporary control operations are required to limit the emergence until such time as the more permanent controls are established. Since 1931 experimental applications of insecticides have been made by hand, ground equipment and aircraft; however, until the availability of DDT no practical results were observed.

The experiments of Hansens, Carpenter and Hart in 1946 and 1947 proved that applications of DDT dusts to the meadow surfaces when dry killed the newly hatched larvae as the treated areas became flooded. In 1948 some 300 acres were dusted with airplanes using 300-mesh agricultural DDT dust at the rate of 1 pound of DDT per acre. It was apparent that the agricultural grade of dusts was too light for aerial application, that the dust did not penetrate the vegetation to reach the ground surface and that wind conditions made the periods of application too limited for practical application.

In 1949 the Volclay Corporation was asked to develop two grades of bentonite dusts, one of approximately 30-mesh screening and the other of approximately 80-mesh screening. These dusts were impregnated with 10% DDT and applied by aircraft. Observations indicated that both coarse dusts penetrated or rolled off dry vegetation to reach the ground; however, if the vegetation was wet, as is usually the case in the mornings, the bentonite stuck to the vegetation and disintegrated. Furthermore, the periodic rainfalls, not sufficient to cause flooding, caused the bentonite to jell and stick to the vegetation.

During the same year, the Tobacco By-Products and Chemical Corporation supplied us with test samples of waste tobacco stems ground to approximately 30-mesh screening and impregnated with 10% DDT. In preliminary tests, this material reached the ground and was not affected by occasional wetting.

1950 Tests. Two meadow areas were selected for tests in 1950, one consisting of 126 acres and the other of 75 acres. Both were of similar type with the typical meadow vegetation of calamus (*Acorus calamus*) and smartweed (*Persicaria hydropiper*). The meadow areas were surrounded by high trees.

The margins of both tracts were dusted with bentonite dust on July 2, 1950, at the rate of 1.5 lbs. of DDT per acre. The dust was restricted to a 100-foot band defined by the 170-foot contour. The center of the larger tract, elevation 166 feet, was dusted with 10% DDT tobacco stem dust at the rate of 2 lbs. of DDT per acre. The center of the smaller tract was not dusted. The purpose of the band dusting was to test a theory that flood waters must reach the 170-foot contour to remain on the meadows long enough to permit mosquitoes to emerge. Observations over many years indicated that developing larvae, several days after hatching, were concentrated in the shallow, grass-protected margins of the flood waters.

On July 10 and 11, a total of 3.84 inches of rainfall flooded the center portions of both tracts but the flood waters did not

reach the bands. Observations made within the following week indicated no mosquito larvae on the treated center portion of the larger tract; however, many larvae were found in the center portion of the untreated small tract. No floods occurred during the balance of the season and observations on the effects of the band treatment could not be made.

1951 Tests. On May 22 and 23 a total of 12,000 lbs. of tobacco stem dust, impregnated with 10% DDT, were applied to 955 acres of meadow land in the Passaic Valley. The dosage ranged from 1 lb.-1.5 lbs. of DDT per acre. At the time the area was dry and due to the weight of the dust, temperature and winds up to 15 mph had little effect on the aerial application. No effort was made to repeat the banding tests and the test plots were completely dusted.

A minor flood occurred on May 24 and no mosquito larvae were observed on the dusted meadows whereas many larvae were found on the untreated areas. Repeated wettings of the entire area took place during June and July. On July 28 a minor flood put 18 inches of water over the treated plots.

Observations made after the flooding indicated 90–95% control of mosquito larvae as compared with non-treated areas. It should be noted that observations were made in the areas where dusting had been most difficult due to nearby trees or other obstructions that made uniform application difficult, and that two months and repeated wettings had taken place prior to the flood of July 28.

CONCLUSIONS

From tests made with DDT dusts as a prehatch control of *Aedes vexans* larvae over a period of 6 years it is apparent that satisfactory results may be obtained by the application of heavy or coarse dusts in the 30–80 mesh screen range provided application is made when the breeding areas are dry. Applications may be made by ground equipment or airplane, making sure to provide a uniform distribution. Procedures have become standardized, and in our situation the suggested rate of application is 1.5 lbs. of DDT per acre applied in the form of a heavy or coarse organic dust impregnated with 10% DDT solution.

Future Plans. Now that the method has become standardized it is proposed to investigate the build-up of DDT residual year by year over the treated areas.

This will permit a prescribed dosage each year to maintain a pre-season effectiveness equal to 1.5 lbs. of DDT per acre. It is also proposed to make both chemical and entomological tests of the flood waters to determine the concentration of DDT in the run-off. In short, our work in 1952 will be largely directed at the analytical side of the problem to determine what takes place when prehatch control is practiced over extensive areas.

SUMMER FIELD TRIP FROM OTTAWA

A mid-summer field trip is being planned for the membership on the invitation of President Twinn. Tentative arrangements involve the assembly at Ottawa, Canada on the evening of July 29 or the morning of July 30. Two days will be devoted to the inspection of Dr. Twinn's laboratories and of field problems and operations. An evening session will be held on July 30 to discuss current control problems.

Those interested should contact Robert L. Vannote, 3 Franklin Place, Morris Plains, N. J., for details. Mr. Vannote has notified the Regional Directors so that the above information should already be in the hands of the members in case this number of MOSQUITO NEWS does not reach them before the trip.

A STUDY OF ADULT MOSQUITO CONTROL WITH AEROSOLS AT FORT LAUDERDALE, FLORIDA

A. E. GRIFFITHS [1] AND O. E. WHITE [2]

Since 1946 there has been an increase in the use of thermal aerosols carrying primary toxicants for the supplemental control of mosquitoes and other insects. Aerosols are clouds of droplets, mostly below 50 microns diameter, of petroleum oils in which are dissolved DDT, BHC, lindane, and other toxicants. The aerosol oils employed range from kerosene and fuel oil to Sovacide F. The latter material is specifically manufactured for thermal aerosol generation and has a greater solubility power for chlorinated toxicants than kerosene or fuel oil. S/V Sovacide F is in itself toxic to insects.

The use of fogs for the control of adult mosquitoes is primarily a supplementary operation designed to give immediate relief from invasions of these insects. Under conditions of heavy breeding, as found in marshes and swamps, the aerosol fog method of adult control does not replace the recognized and basic practices of drainage and larviciding.

In 1950 and 1951 Fort Lauderdale embarked upon a program of adult mosquito control in residential areas supplementary to the excellent work of the Broward County Anti-Mosquito District. The municipal program, which was carefully coordinated with the County program, included basic larviciding procedures as well as weekly street-by-street fogging with lindane, BHC, or DDT in S/V Sovacide F or No. 2 fuel oil. Three or four TIFA units were employed for the fogging treatments. One of these units was mounted on a motor-propelled catamaran which permitted fogging of both banks of the 290 miles of canals found within the city limits of Fort Lauderdale.

The city used approximately 13,000 gallons of S/V Sovacide F and 36,000 gallons of No. 2 fuel oil for fog or larvicide in 1950, and 24,000 gallons of S/V Sovacide F in 1951. In 1951 fuel oil was limited to the larvicide phase of the work. These petroleum carriers were used to disperse approximately 10,500 lbs. of DDT and 600 to 2,400 lbs. of lindane or BHC. Early in the season it became apparent to the Director of Insect Control that fog produced by S/V Sovacide F covered at least twice as much area as the fog from an equivalent volume of No. 2 fuel oil. Initial "knockdown" of mosquitoes was better and, in addition, the high solubility of S/V Sovacide F for the chlorinated toxicants reduced formulation time to a fraction of that required when fuel oil was employed.

The initial success of the aerosol adulticide phase of the Fort Lauderdale program was amply confirmed by the reports of residents. The immediate relief from insect attack experienced after fogging in areas heavily infested by mosquitoes was common knowledge. These reports were empirical, however, and gave no information on duration of relief. In view of this, it was desirable that factual data be obtained on the following points: Do aerosols effectively kill adult mosquitoes? How long are aerosols effective? What procedures in aerosol application should be followed to insure maximum effectiveness?

Experimental Studies. During the period covered by the brief field tests, *Aedes taeniorhynchus* predominated. An initial survey within the corporate limits of Fort Lauderdale indicated that the primary emergence areas were the salt marshes and mangrove swamps east of the city. Smaller secondary breeding areas were observed on undeveloped or partially developed

[1] Socony-Vacuum Oil Co., Inc., New York, N. Y.
[2] Director of Insect Control, Fort Lauderdale, Florida.

"islands" within some residential districts.

In order to obtain estimates of the density of mosquito populations prior to and after fogging, the numbers of mosquitoes landing on the legs and arms of observers were determined during test periods of one minute at 10 stations in several areas. At these stations simultaneous counts were taken by three observers, one hour before the area was to be fogged, and at intervals of 2, 12, 24 and 48 hours after fogging. The data, in the form of the average number of landings per minute for all three observers before and after fogging, are given in Table 1.

TABLE 1.—Per cent reduction in mosquito populations following application of S/V Sovacide F fogs plus 0.5% lindane

	Percent Control Based on Landing Counts Before Fogging			
	2 Hours After	12 Hours After	24 Hours After	48 Hours After
Type of Area	%	%	%	%
Residential; No Emergence, 0.5–1 Mile	89	88	77	2
Residential; Emergence within 0.25 Mile	47	63	85	30
Dense Salt Marsh; Heavy Emergence	55	3	0	0
Ditched Salt Marsh; Moderate Emergence	76	50	65	0

The 10 stations were selected to typify four known conditions of infestation: (a) residential area, no known emergence within 0.5 to 1.0 miles; (b) residential area, moderate emergence within 0.25 miles; (c) dense salt marsh or mangrove swamp, heavy emergence; (d) open or ditched salt marsh, moderate to heavy emergence.

The tests were not isolated experiments but were coordinated with the standard procedure of fog application followed by the Director of Insect Control during the early summer of 1951. This consisted of an approximately weekly fogging of all areas of the city, according to an orderly plan. During the period of the tests the fog material consisted of 0.5% lindane dissolved in S/V Sovacide F. DDT is also employed by the city at the rate of 7.5% in S/V Sovacide F but, due to an increasing resistance of some species of mosquitoes, lindane has proved to be more effective. S/V Sovacide F with lindane was fogged at a rate of 10 gals. per hour from TIFA units mounted on trucks or jeeps traveling at a rate of 4 mi./hr. Fogging operations were conducted from 4 p.m. to 10 p.m. and from 4 a.m. to 8 a.m. During the spring and summer months, east or southeast winds of 2 to 4 miles per hour prevail, so most fog operations took place from the east side of residential blocks. Under good conditions the fog was sufficiently dense to drift down wind through the entire block—a distance of 300 ft. or more. During one test under the above conditions, approximately 385 acres were fogged by one TIFA unit in 4½ hours, or 45 gallons of insecticidal solution were applied over the area. This was equivalent to an approximate output of 0.12 gal. of solution per acre. At this rate, the output of lindane from an 0.5% solution was approximately 0.005 lb./acre, and in those applications where DDT was employed, the output of DDT from a 7.5% solution was 0.07 lb./acre.

Table 1 summarizes the mosquito landing counts made during the tests, in terms of percent reduction of mosquitoes based on landing counts immediately preceding fog application. Of primary interest are the data for residential areas at some distances from emergence sources. Under these conditions where annoying invasions were intermittent, an average of 89% reduction in population was obtained within 2 hours after fogging with 0.5% lindane in S/V Sovacide F. Effective relief from annoyance continued for at least 24 hours. Tests conducted in residential areas close to secondary emergence places do not show as great an initial reduction (47%—2 hrs.; 63%—12 hrs.) as observed in more distant residential districts, but relief from annoyance was noticeable.

Table 1 also shows that although a significant reduction of adult mosquitoes followed fog application in ditched mangrove swamps, the effect disappeared rapidly after 24 hours. In dense swamp, there was no significant reduction in population after two hours. The greater effectiveness of fogs in the ditched mangrove swamps possibly resulted from the dense aerosol clouds which were able to move down the main ditches and into the feeder or lateral ditches. This may have provided deeper penetration into the dense masses of vegetation.

The data discussed above re-emphasize the supplemental and temporary nature of thermal aerosol fogs in adult mosquito control. Where employed with a full understanding of these limitations, aerosol fogs appear to offer quick and even spectacular relief from local mosquito invasion.

Variability of Mosquito Landings on Individuals. In the study reported, three observers made simultaneous landing counts for one-minute periods at 10 stations at various intervals with relation to the time of fog application. A consistent variation in the rate of mosquito landings (*Aedes taeniorhynchus*) was noted by each of the three observers. Obviously, if a consistent difference exists in the degree of repellency or attraction shown toward mosquitos by individuals, fallacies may be introduced with attempts to sample populations by the landing count method.

To establish the significance of individual response, a statistical analysis was made of the landing counts for the entire study. This analysis is summarized in Table 2. The data in Table 2 indicate that the lower rate of mosquito landings reported by Observer #1, in comparison with counts reported by Observers #2 and #3, is highly significant. In each case, the differences in counts between Observers #2 and #3 and Observer #1 exceed the least significant difference (5.25) required at the 1% level. Simply stated, this means that the odds are 99:1 against the probability that the observed difference occurred by chance alone. It is also evident that a significant difference exists between Observer #2 and Observer #3, although significance is of a lower order (odds of 19:1 against chance occurrence).

No attempt was made to determine the cause of individual difference in repellency or attraction for mosquitoes. This was a basic problem beyond the scope of the study. The existence of such variation appears to emphasize the desirability of employing two or more observers simultaneously when landing counts are

Table 2. Analysis of mosquito landings per minute (*Aedes taeniorhynchus*).

	Observer #1	Observer #2	Observer #3
Mean	10.4	16.1	19.7
Difference	—	+5.7	+9.3

Difference for significance @ 1% (99:1) — 5.25
Difference for significance @ 5% (19:1) — 3.26

used as indices of the density of mosquito population.

CONCLUSIONS AND RECOMMENDATIONS:

1. During the 1951 routine fogging at Fort Lauderdale, Fla., operations were conducted between 4 and 10 p.m., and between 4 and 8 a.m. The periods between 4 and 8 p.m. and 6 and 8 a.m. are daylight periods when, under south Florida conditions, undesirable inversion currents and wind changes often prevent the uniform distribution of aerosol fogs at ground level. Under these circumstances, a large proportion of the aerosol may quickly dissipate and thus become ineffective. In order to conserve insecticide and to obtain maximum control of mosquitoes, it was suggested that all fog operations be carried on during the night between 9 p.m. and 6 a.m.
2. The 7.5% DDT formulation, together with the existing rate of application at Fort Lauderdale resulted in the distribution of 0.07 lb. of DDT per acre fogged. Previous investigations, as reported by the Des Plaines Valley, Illinois, Mosquito Abatement District indicate that effective adult control is obtained where 0.1 to 0.3 lb. of DDT are distributed per acre. These dosages are substantially lower than the 2 lbs. per acre adopted as the proper limit for safety of birds by the U. S. Fish and Wildlife Service.

   Taking all things into consideration, it was suggested that from 10% to 15% Technical DDT be employed in future fog operations at Fort Lauderdale when DDT is the prescribed toxicant. This concentration assumes TIFA output rates of from 10 to 20 gals./hr. and a vehicle speed of 4 to 5 miles/hr. Under these conditions approximately 0.1 to 0.3 lb. of DDT will be distributed per acre.
3. The lindane formulation (0.5%) used for fogging at Fort Lauderdale resulted in the distribution of approximately 0.005 lb. of lindane per acre. There is little information concerning minimum effective amounts of lindane when applied as a thermal aerosol for adult mosquito control. However, lindane is considered to be approximately 10 times more effective than DDT; thus, on an acre basis 0.01 lb. of lindane should be distributed to be equivalent to 0.1 lb. of DDT. At the rate of fog application in this study, a 1% solution of lindane was suggested in place of the present 0.5% formulation.
4. The rate of fogging at Fort Lauderdale (10 gals./hr.) produced a very dry fog and resulted in no visible oil deposition on foliage close to the generator. This type of fog is effective in killing mosquitoes in residential areas. However, where slight deposit of oil on foliage may be unimportant, it was suggested that the generator output be increased to 15 or 20 gals./hr. This rate of application will improve initial kill of adult mosquitoes and the duration of control in marshes and in areas adjacent to them.
5. When data on mosquito populations are obtained by the landing count method, variations in the degree of repellency or attraction for the insects by individual observers should be taken into consideration. It is recommended that two or more observers be employed when landing counts are taken.

If you have not already purchased a copy of AMCA Bulletin #2, "Ground Equipment and Insecticides for Mosquito Control," place your order soon. The information it contains is indispensable to mosquito control workers. Copies of the Bulletin are still available at $2.00 each. Orders should be sent to Mr. C. T. Williamson, Suffolk Co. Mosquito Control Commission, Yaphank, N. Y.

RESIDUAL AND SPACE SPRAYS FOR THE CONTROL OF SNOW-WATER *AEDES* MOSQUITOES IN CAMP AREAS

ROBERT A. HOFFMAN AND ARTHUR W. LINDQUIST
U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine

The snow-water *Aedes* mosquitoes of the Cascade Mountain area of Oregon are very annoying to workers, campers, sportsmen, and livestock, and are a major obstacle in the development of the area for recreational purposes. Throughout the Cascade range the adult mosquitoes, principally *Aedes communis* (DeG.), *A. fitchii* (Felt and Young), *A. hexodontus* Dyar, *A. cinereus* Meigen, and *A. excrucians* (Walker), may be active from May through mid-August depending somewhat on elevation and seasonal snow conditions. As the economy of the area is based largely on the logging industry and the natural recreational attractions, a serious problem has developed during the mosquito months.

In 1950 and 1951 studies were conducted to find a practical means of protecting the work camps, campers or picnickers, summer residents, and others from mosquito annoyance. Both residual treatments and space sprays were utilized in these tests.

RESIDUAL SPRAYS

Several insecticides have been used as residual sprays on vegetation in experiments on the control of salt-marsh *Aedes* mosquitoes and certain anophelines. Madden *et al.* (1945) treated foliage and ground litter on ½- and 1-acre plots with DDT and obtained good control for as long as 2½ months. Fluno *et al.* (1949) obtained effective control of *A. taeniorhynchus* and *A. sollicitans* with DDT, chlordane, benzene hexachloride, or toxaphene for at least 11 days under favorable weather conditions. Ludvik (1950) reported satisfactory control of *Anopheles quadrimaculatus* with DDT by treatment of a barrier strip 50 feet wide.

Relation of Mosquito Habits to Effectiveness of Residual Sprays—For a residual spray to be effective the mosquitoes must remain in contact with the toxic residue long enough to become affected and reinfestation of the area must be at a slow rate. Observations of the flight habits of the snow-water mosquitoes revealed that each day large-scale movement occurred only between 8 and 10 p.m. (D.S.T.) at temperatures of 50° to 64° F. and under sunset to twilight conditions. Since activity invariably ceased at an evening temperature of 50–52° F., campers were able to spend the late evening and night without mosquito annoyance.

Selection of resting places by adult mosquitoes varied with the available foliage, but grass in moist situations appeared to be preferred. In pine or fir forests adults could be found on both surfaces of low-hanging leaves and in cracks and crevices of tree trunks where no low foliage was available. These habits and the fact that only one generation matures each year indicated that application of an insecticide on foliage could provide at least fair control of the adult mosquitoes within the treated area.

The experimental plots were scattered over the mountain area in order to provide variation in foliage conditions, altitude, and topography. Ground cover ranged from dense grass to bare ground, secondary cover from thickets of rhododendron, bitter brush, and scrub pine to none at all, and the primary cover from open pine to dense Douglas-fir forests. Altitudes ranged from 3600 to 5600 feet above sea level.

Tests with Residual Sprays—In the two years in which the tests were conducted, 41 plots varying in size from 0.25 to 50 acres were treated in June or July with either wettable powder suspensions or emulsions of DDT and of lindane. In 1950, 20 plots were treated with an

orchard-type sprayer capable of delivering 4 gallons per minute at a pressure of 300 pounds per square inch. Where service roads were available, this equipment was very satisfactory, but in plots remote from roads great lengths of hose were necessary.

In 1951 the applications were made with a portable mist blower (Potts and Spencer 1947). With this blower it was possible to obtain good coverage with small volumes of concentrated sprays and thus reduce the amount of fluid and the application time. The portability of the equipment also made it valuable in treating brushy areas inaccessible with a larger conveyance.

A 50 per cent wettable powder and a 25 per cent emulsifiable concentrate of each insecticide were used as the stock preparations. They were generally diluted with water to 5 per cent for use in the mist blower and to 1 per cent for the orchard sprayer. The sprays were applied in about 20- to 30-foot swaths wherever possible, and an attempt was made to distribute the material on all foliage or structures to a height of approximately 10 feet.

Control was evaluated by counting the mosquitoes alighting on the front of a person's clothing in 30 seconds after the person had stood motionless for the previous 30-second period. Many such counts were taken each day, both before and after treatment, and the counts of any one day totaled and averaged. Counts made in adjacent untreated areas were used to compute per cent control.

Table 1 gives results obtained in selected plots treated with DDT. All plots larger than 0.5 acre gave good daytime control but little or no control during the evening migration period. The smaller plots provided more erratic results, but they received daytime protection from 17 to 95 per cent above that of untreated adjacent areas (not shown in table).

Failure in two plots to control adults for 10 days or longer in 1951 is attributed to their location adjacent to a meadow that was considered to be the principal source of mosquitoes for the entire area (data not shown in table). It is believed that sufficient adults were able to fly into the treated areas without contacting treated foliage to maintain populations great enough to invalidate residual control measures. On all plots control varied somewhat with the environment, but in general control of 65 to 100 per cent was obtained for the remainder of the mosquito season (30 to 45 days).

In plots treated with lindane at one and three pounds per acre, populations were 55 to 93 per cent below those in adjacent untreated areas during 42 days of observation. The 3-pound dosage gave about the same control as the DDT treatments at four pounds, but at one pound lindane was less effective than DDT at two, four, or six pounds.

No difference could be demonstrated between suspensions and emulsions of DDT. The emulsions, however, were easier to apply with the mist blower and appeared to give more rapid knock-down of mosquitoes. Results of application of residual sprays with either of the two types of equipment previously mentioned did not appear to differ, and it is believed that any available and convenient spray equipment will give similar results.

SPACE SPRAYS

In 1950 protection of a camp area from snow-water *Aedes* mosquitoes was tried by use of stationary mist sprayers placed to the windward of the area. The equipment consisted of six to eight hand-made spray heads of the suction-feed type secured to Mason-jar lids, quart Mason jars, 50-foot lengths of ¼-inch air hose, and a compressor capable of supplying 4 cubic feet of air. When six units were used, each unit was capable of delivering approximately 7 cc. of fluid per minute. A solution containing 20 per cent of DDT in an aromatic oil was used as the spray. No DDT crystallized from this solvent at temperatures above 30° F.

Operation of the equipment during the evening flight period did not provide very good control, mainly because DDT is

TABLE 1. Results of typical tests with DDT residual sprays applied on vegetation for control of snow-water *Aedes* mosquitoes.

Dosage, Pounds Per Acre	Area of Plot, Acres	Foliage Conditions of Plot	Pre-treatment Count	Per Cent Control After— 1 day	2 days	6 days	8 days	13 days	21 days	28 days
1950										
6	0.8	Semi-open	15	—	—	—	91	—	100	97
4	0.6	Open and semi-open with tall grass ground cover	8	67	—	—	100	89	[1]	—
	1.0	Dense tree cover with shrubs and grass ground cover	20	—	—	74	—	[1]	88	93
	1.2	Very dense grass, shrub, tree area	17.5	95	—	—	100	91	[1]	—
2	1.0	Dense tree cover, shrub secondary dense, heavy grass ground cover	10	—	—	83	—	[1]	66	90
1951										
2	2.0	Narrow trail with dense brush margins	14.75	—	100	—	98	77	[2]	—
	0.8	Semi-open primary cover; dense grass ground cover	5.4	100	—	—	76	72	—	7
1	0.5	Dense	13.7	—	100	—	90	77	100	—
	3.0	Semi-open to dense	6.03	—	100	—	96	95	100	—
	2.0	Open grass to dense cover	5	91	—	—	—	85	76	[1]

[1] No activity.
[2] Very little activity.

slow-acting and did not kill the mosquitoes fast enough. Application of DDT in this manner, however, did leave a residue on vegetation in the surrounding areas so that good daytime control was obtained.

Reductions of 73 to 86 per cent of the mosquitoes resulted from a daily 10-minute morning operation of this equipment, and this control was maintained throughout the day until the evening migration.

In 1951 mist-spray tests were devised primarily for the control of snow-water mosquitoes in a small area such as might be used for a family picnic or camping site. Since it was obvious that quick knock-down agents would be necessary, pyrethrum and allethrin were used as toxicants. DeVilbiss spray heads of the suction-feed type were utilized, as they were more easily adjusted and maintained than the home-made spray heads used in 1950. The spray units were connected by 50-foot lengths of hose, so that they could be moved about freely and placed in position to obtain the most value from the spray. A portable gasoline-powered compressor provided the air pressure. All tests were conducted in the evening during the peak of mosquito activity.

Two spray heads about 30 feet apart effectively controlled adults in an area approximately 40 feet square while dispensing 7.5 ml. of 0.2 per cent allethrin per head per minute. However, control was obtained only while the unit was in actual operation; as soon as it was shut off, immediate infiltration of the area was noted. No definite mosquito mortality was observed, but they showed a tendency to avoid the area as if the spray were a repellent.

In tests with 0.4 per cent of allethrin or pyrethrins dispensed at 8 to 10 ml. per head from two spray heads, excellent control was obtained in an area 30 by 40 feet. In one series in which the units were alternately operated for 5 minutes and shut off for 10, complete protection was provided during the operating periods and at least 50 per cent during off periods. No outstanding difference in control was noted between the toxicants at this concentration under our rough field-test conditions. Affected mosquitoes, as well as other insects, were observed during spraying of both toxicants at a concentration of 0.4 per cent, which demonstrates that the protection obtained resulted from mortality of insects rather than a repellency.

In one series in which two units dispensing 7.5 ml. of 0.4 per cent allethrin per head were set up 25 feet apart, good control was obtained in an area 30 feet square while the units were operating, but large numbers of mosquitoes again infested the area soon after the units were turned off. Sprays containing both 0.2 and 0.4 per cent of pyrethrins gave similar results.

Summary.—Tests with residual and space sprays were conducted during 1950–51 in the Cascade Mountain areas of Oregon for the control of snow-water *Aedes* mosquitoes. These mosquitoes were found to migrate very little during the daytime, but in the evening between 8 and 10 p.m. (D.S.T.) at temperatures of approximately 64° to 52° F. migration and biting activity were high.

Residual treatments on plots of 0.5 to 50 acres controlled adults at all times of the day except during the 2-hour migration period. DDT at one to six pounds of active material to the acre gave satisfactory control. Lindane at three pounds gave control similar to DDT at four pounds, but at one pound was somewhat less effective.

Space sprays applying DDT in oil for two 10-minute periods about 12 hours apart provided protection except during migration. Space sprays containing 0.2 or 0.4 per cent of pyrethrins or allethrin gave satisfactory control in limited areas during the evening migration period.

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PROTECTION FROM NORTHERN BITING FLIES

B. HOCKING

Department of Entomology, University of Alberta

Introduction

A great deal has been published on the use of repellents against biting, and especially disease-transmitting insects. Rather less has been written on the use of protective clothing. The general subject of the protection of the individual, whether human or animal, has received but little attention.

In malaria control, this problem is one of the absolute prevention of biting. In relation to northern species of biting flies, which are principally of importance on account of the more direct effects of their attentions, the approach is different. The absolute prevention of biting, even if it were possible, is unnecessary and perhaps even undesirable. The general nature of the northern biting fly problem has been reviewed by West (1951) and by Twinn (1952). The only presently available alternative solution to the mosquito and blackfly problem is the direct use of insecticides. For the tabanids there seems to be no alternative. There are no immediate prospects of ecological or biological controls for any of the three important groups. The use of insecticides is less promising against northern species than against *Anopheles*, largely because of their much greater dispersal power. Treatment of areas in proportion to the square of this range of dispersion is necessary if lasting relief is to be obtained, and travel and transportation over these areas are also more difficult. The methods of personal protection are thus practically promising as well as being ethically attractive.

The Factors which Attract Biting Flies

No scientific approach to the problem of personal protection from biting flies is possible without an understanding both of the factors which attract these insects to their hosts, and those which stimulate them to feed. This understanding has only recently been much sought after, and, although important contributions have recently been made by Brown *et al.* (1951), Sarkaria and Brown (1951), Peterson and Brown (1951) and Brown (1951), it is still far from complete. It is itself dependent on a knowledge of the sensory physiology of the insect in question, which also, in spite of recent contributions (Roth, 1951), is still inadequate. Some of the more important information on this subject is summarized in Table 1. Scientific methods of personal protection must be directed at interfering with this mechanism of attraction and stimulation, and when this interference fails, at mitigating the resulting effects.

The Effects of Biting Flies on Man and Animals

Direct effects

There are many reports, not all of them authentic, of men and animals being killed by northern biting flies. Current

methods can protect men entirely against such occurrences without an excessive expenditure of time or materials. There remain, however, very considerable discomforts and delays, risks of secondary infections, and sometimes reactions to the bites which may require hospital treatment. In a really intense blackfly and mosquito population, conversation and even breathing become difficult unless one is prepared to swallow or inhale many of the insects. The effects of biting flies on

TABLE 1. Factors which may influence the attraction and feeding of northern biting flies.

Sense and Stimulus	*Groups of flies in which operative*	*Authorities*
Chemical Senses		
Moisture	Mosquitoes	(van Thiel, 1939 (deLong *et al.*, 1946 (Brown, 1951 (Brown *et al.*, 1951
Carbon dioxide	Mosquitoes	(Rudolfs, 1922 (Brown, 1951 (Brown *et al.*, 1951
	Blackflies	(Dalmat, 1950
Smell	Mosquitoes	(Rudolfs, 1922 (Mer *et al.*, 1945 (DeLong *et al.*, 1946 (Brown, 1951 (Brown *et al.*, 1951 (Sarkaria & Brown, 1951
Taste	No studies known	
Visual sense		
Colour	Mosquitoes	(Nuttall & Shipley, 1901–3 (Gjullin, 1947 (Brown, 1951
	Blackflies	(Davies, 1951
	Tabanids	Portchinsky, 1915
Movement	Tabanids	(Stone, 1930 (Twinn *et al.*, 1948
	Mosquitoes	(Kennedy, 1939 (Haddow *et al.*, 1947
Mechanical Senses		
Surface texture	Mosquitoes	Brown, 1951
Thermal Sense		
Radiation	Mosquitoes	Peterson & Brown, 1951
Temp. gradient	Mosquitoes	(Howlett, 1910 (Marchand, 1920 (deLong *et al.*, 1946 (Brown, 1951 (Peterson & Brown, 1951

man and animals may be divided into physiological and psychological effects, although there is some overlap.

The simplest physiological effect of biting fly attack is the loss of blood; a calculation on this is of interest. The most intense conditions of mosquito attack studied in northern Canada to date were such that a man would receive about 280 bites on the forearm from wrist to elbow, on exposing this for one minute. The total skin surface is about 33 times that of the forearm, so that a completely unprotected man—and many fabrics used for summer clothing give very little protection—could receive a maximum of 9250 bites per minute. The average weight of a blood meal is not less than 2.5 mgms., so that the blood loss would be at least 23.1 gms. per minute. At this rate a man would lose half his blood, which would probably prove fatal, in about 1¾ hours. Blackflies and tabanids may be present at the same time, and although the biting rates for these are usually much lower, the loss of blood from their larger punctures, in which an anticoagulin is present, would be considerable. Fortunately the conditions necessary for such intense attack are rare and of short duration.

The reaction to bites

With reference to the reaction to mosquito bites, Macloskie (1888) regarded the middle lobe of the salivary gland as the source of the poison concerned. Schaudinn (1904) and Roy (1927) demonstrated somewhat inconclusively that the reaction is due to an enzyme produced by constant commensal fungi or yeasts, living in the oesophageal diverticula. The results of Cornwall and Patton (1914) seem to support this view, and Hindle (1914, p. 68) quotes other work in support of it, and states that the fungus, one of the Entomophthoraceae, is transmitted through egg, larva, and pupa. Bruck (1911) however, extracted a toxin which he named *culicin* from the bodies of mosquitoes and assumed this came from the salivary glands, and McKinley (1929) has convincingly demonstrated the presence of a poison in the salivary glands of *Aedes aegypti*. Hecht (1927) also supports this view, explaining Schaudinn's results as a general effect, produced by any mosquito tissue. None of this work relates to northern species of *Aedes*.

The toxic effects of blackfly bites are much more serious than those of mosquitoes but have been less studied. Stokes (1914) was able to reproduce the characteristic lesions by hypodermic injection of various extracts of the head and thorax. Patton and Evans (1929, pp. 140–150) suggest a toxic enzyme in the saliva as the irritant. The reduction in the reaction shown by an individual as the season advances has been generally regarded as attributable to the development of immunity; it could equally well be due to physiological differences in the later generations of the insect. Observations on the reactions to the bites of tabanids are very few, but the reaction may certainly be quite serious (Miller, 1951).

More recently, the allergic nature of the reactions to arthropod bites generally has been realized (de Meillon 1949, Heilesen 1949, Gordon and Crewe, 1948, 1950) with a resultant reduced interest in the origin of the toxic material.

Disease transmission

None of the northern species of biting flies is known to serve as a true vector for any disease or parasite of man in northern areas. The possibility of mechanical transmission of disease is also remote at present, in view of the shortness of the season, the very sparse human population, and the resulting improbability of any individual insect taking blood meals from two humans. Perhaps some encephalitides may prove to be of importance. Diseases of this group are believed to be largely transmitted by *Culex tarsalis* Coq. in Washington (Hammon *et al.*, 1942), and probably in Saskatchewan (Rempel *et al.*, 1946), while in southern Manitoba the virus has been recovered from *Culex restuans* (Theo.) Norris, 1946). Elsewhere, species of *Aedes* are vectors of these diseases, and Madsen *et al.* (1936)

have shown laboratory transmission by *A. dorsalis* (Meig.) and by *A. nigromaculis* Ludl., the latter species recorded from Churchill, Manitoba, by McClure (1943) in 1936 but not found there since.

Transmission from animal reservoirs must be regarded as less unlikely, and transmission of animal diseases is perhaps common. *Simulium venustum* Say transmits an important disease of ducks caused by *Leucocytozoon anatis* Wickware closely related to the malaria plasmodia (O'Roke, 1930). Scott (1920) has shown that *Hybomitra septentrionalis* Loew is capable of transmitting swamp fever or infectious anaemia of horses, and various workers (Roubaud & Colas-Belcour 1937, Yen 1938) have demonstrated the ability of the filarial parasite of dogs *Dirofilaria immitis* Leidy to develop in *Aedes cinereus* Meig., *A. punctor* Kirby, and possibly *A. flavescens* Müll., and *A. excrucians* Wlk. Tularaemia and *Plasmodium gallinaceum* have also been transmitted experimentally by *H. septentrionalis* (Parker, 1933) and *A. cinereus* (Olin, 1942), and by *A. campestris* D. & K. (Cantrell & Jordan, 1945) respectively.

Psychological effects

The psychological effects of biting fly attack may be no less serious than the physiological effects. These effects result partly from the stinging sensation of the insect mouthparts, partly from the manual *removal reaction* to this, and partly from the continual noise and the impact of insects on the face and person. The tabanids and the mosquitoes are much more important in connection with these effects than are the blackflies. Initially, it requires the bite of an insect to evoke the removal reaction; as the severity and duration of exposure are increased it is soon evoked by insects alighting on the skin, and finally in many individuals by non-existent insects, the hallucination of an insect biting being unquestionable.

Psychological effects can rapidly cause a serious reduction of individual efficiency, and a still more serious lowering of group morale. Under very intense attack most individuals would become ineffective far sooner from psychological than from direct physiological causes. The rapidity with which a susceptible person can become worked up into an emotional state bordering on dementia, as a result of the continually accelerated and increasingly ineffective removal reactions, has to be seen to be believed.

A stage beyond excessive use of the removal reaction is that of running away, a normal reaction on the part of many animals to the attentions of flies. While temporary freedom from mosquitoes and blackflies can sometimes be obtained by running into the wind, this is a most effective method of assembling a large population of tabanids. The direction of caribou migration may well be in part determined by that of prevailing winds during the mosquito season (Seton, 1912, pp. 209, 257).

EXTERNAL PROTECTIVE DEVICES

Smudge Fires

One of the oldest, and still a widely used protective device is the smudge fire. Among the best ingredients for such a fire is damp moss, fortunately a usual feature in the flora of biting fly infested areas. A strong wood fire is established first and thereafter a nice balance is maintained between wood and moss. Such a fire in the doorway of a cabin, although less effective, is cheaper and not very much more inconvenient than screening. The protection of a series of such fires will be actively sought by livestock when flies are bad. Medical authorities disagree regarding the long term effects of the smoke on man and livestock.

Repellents

While great improvements have been made in materials for application to the skin or clothing for protection against biting flies, these have been almost entirely the result of empirical testing, mostly against *Anopheles* and *Aedes aegypti*, of a very large number of per-

missible materials (Linduska & Morton, 1947, Travis *et al.*, 1949). These materials have been found to show similar effectiveness against northern species (Applewhite & Smith 1950, De Foliart 1951, Travis & Smith 1951), although the failure of 2 phenyl-cyclohexanol against blackflies is an exception. It seems unlikely that further significant advances can be made without a more fundamental approach on the lines already indicated. The superiority of most of the more recently discovered materials over the now established dimethyl phthalate and ethyl hexanediol can only be demonstrated by careful tests, and is not of great practical significance. Plasticising properties and irritant effects are shown by so many of these materials that they would almost seem to be a *sine qua non* of repellency. These properties, and the still rather ephemeral nature of the protection given under severe conditions, are the principal difficulties. Rubzov (1939), however, has claimed that cinnamon oil remains effective against blackflies for 24 hours. Most recently developed materials, inasmuch as they show little action at a distance, and must be applied as a complete if tenuous film, appear to act through the gustatory rather than the olfactory senses of the insect. This difference from some of the older materials is not always appreciated by the user, who may thus fail to get full advantage of their superior properties. Gustatory repellents of course have potentially greater persistence.

Problems also exist in the formulation and dispensing of these materials; there is much to be said for a solid or semi-solid preparation (Cameron 1946, 1948), which may avoid the need for a bulky container, and the risk of spilling. If a liquid form is preferred a glass bottle, in spite of its wide use, is probably the least suitable container. A metal oil can type of container with a small spout fitted with a screw cap is very suitable. Bulk dispensers of the type employed for liquid soap, mounted at the exits from tents and buildings have proved very useful (Myler, *in litt.* 1947).

Protective clothing

One of the methods by which greater persistence has been sought with some success, is impregnation into normal, or partially protective clothing. Fully protective clothing, however, is the only escape from repeated applications of repellent which is at present possible. In the design of protective clothing there is a threefold problem. Of the three important groups of northern biting flies, the tabanids usually bite only the exposed portions of the body, the blackflies bite the exposed portions and by preference, perhaps, underneath the clothing especially where its constant proximity to the skin facilitates their penetrating this, and the mosquitoes attempt to bite almost indiscriminately on exposed areas and through the clothing, but rarely underneath this. It is necessary then, first, to reduce exposed area to the minimum consistent with comfort and function; secondly, to prevent access by blackflies to the space between it and the body; and thirdly, to prevent mosquito penetration through the clothing to the skin. For most activities in fly country the face, often including the ears, and the hands, must be exposed much of the time. Temporary protection may be afforded to these areas by head nets and gloves. Exposure of the arms to the elbow may be necessary, when arm nets may be worn.

It must be recognized that all types of head net, from ½″ mesh treated with repellent to those fine enough to exclude blackflies without repellent, say 20 mesh, no matter how fine the threads, definitely impair vision. This is particularly true for such activities as shooting. The great majority of them also offer a considerable obstacle to eating, smoking and recognition. Insects which get inside a head net, are as effectively prevented from getting out again as others are from getting in. In traveling through forest or heavy bush country, there is only one item of clothing more likely to be either torn or removed from the wearer than a head net, and that is the arm net.

A form of protection for the head, which is nearly as effective, especially against tabanids and mosquitoes, yet which gets away from all of these drawbacks, has been developed. This consists of a stitched cotton cloth hat with a 3″ brim all round, actually an Indian Army jungle hat, to which a shoulder length fringe of strings is attached at the edge of the brim, with the exception of a space of 5″ at the front. The strings are of cotton, 10″ long and ¼″ apart. This hat has been tried by many people during the last two fly seasons and has been favorably reported on. The idea was developed from a combination of the fly fringe used to protect draught animals in the tropics, and the oil soaked rag placed under the back of the hat and reaching to the shoulders, used by workers on the Hudson Bay Railway. If desired, the fringe may be extended across the front down to eye level, or even full length; vision still remains better than through a net. There is only one item of clothing instead of two; since most head nets require to be worn with a hat. If the fringe is soaked in repellent, the degree of protection is increased. If the wearer of such a hat is attacked in spite of it, a single flick of the head will do duty for several rather elaborate removal reactions.

Entry of blackflies to the space under the clothing is principally via the wrists, neck, and the front openings of shirt and trousers; socks, rubber boots, or puttees worn over the ends of the trousers effectively seal this entry. Although protection may be obtained with double fly closures, undoubtedly the most satisfactory arrangement for the front of the shirt and trousers is the zipper fastener. If the zipper closing the shirt extends fully up to the neck, and this is reasonably closely fitted, this, in conjunction with head net or fringed hat will protect the neck region. Entry at the wrists may be prevented by either a moderately close fit and a band of pile lining, or by a still closer fit alone; a full, sewn in, gusset is essential with either method. Neither is entirely comfortable.

There are two methods by which mosquitoes may be prevented from reaching the skin through the clothing. The first is to use a fabric of such close weave that the proboscis cannot penetrate (Annand, 1945a), that is, with a maximum aperture between threads less than about 0.08 mm. The stylets themselves will pass through holes very much smaller than this, but, with fabric of cotton and synthetic fibres at least, it seems necessary for the tip of the labium to make contact with the skin (Christophers, 1947). While such materials exist (Annand *et al.*, 1945a, b), they are inclined to be expensive and too warm; they may however have other desirable properties, such as wet resistance. The second method is to use a material with a porous, or even a cellular weave, held away from the skin by a partial or complete lining of netting or other material with sufficient thickness to prevent the proboscis of the mosquito from reaching the skin (Annand, 1945b). It would be expected that the combined thickness of the two materials should not be less than the length of the longest proboscides —that is, about 4.0 mm.; in practice however it seems possible to obtain complete protection with a total thickness considerably less than this, perhaps as little as 2 mm. A string vest worn under a cellular cotton shirt gives complete protection and is cool and comfortable in the warmest weather. The lining may be limited to areas such as the back and shoulders where the shirt is in constant close contact with the body. Any clothing which gives inadequate protection may be improved by impregnation with repellents, which is a promising approach to the problem (Smith & Cole, 1951), or by casual application of these to it. These matters have been fully discussed by Christophers (1947).

Because of the now well established fact that more mosquitoes will land on dark coloured than on similar light coloured fabrics it has been recommended that clothing should be light in colour. Inasmuch as large numbers of insects on the clothing may have psychological effects

this recommendation is justified, particularly if fully protective clothing, gloves and head net, are worn. As Hadaway (1951) has pointed out, however, it may well be that flies are driven off light coloured clothing, onto adjoining areas of exposed skin; if this is so, darker colours would be preferable. There is some suggestion that mosquitoes, like the honey bee, will attack more readily through materials of animal origin. Jones (*In Litt.* 1951) has suggested that this may simply be due to differences in moisture content. Commonly such materials are rougher in texture, and this in itself facilitates mosquito activity on them; here too, of course, clothing of more attractive material might well mean less insects on the exposed skin.

Fly proof buildings

Inside buildings, the mosquitoes are much the most important group of northern biting flies. Biting by either tabanids or blackflies indoors is rare except in unusually well illuminated situations such as white tents and sun porches. The provision of darkened shelter for livestock as a protection against these two groups is a well established procedure. However, although they do not bite there, both tabanids and blackflies may be attracted into tents and buildings in very large numbers, and their exclusion is desirable on other grounds.

There are two principles involved in the exclusion of flies from buildings, first, the screening of all openings, including ventilators, drainpipes, and sometimes chimneys, with suitable mesh wire or plastic screening; secondly, the use of double doors at all entrances, preferably combined with a ready means of disinfecting the space between them, as with a pyrethrum aerosol dispenser.

Little has been published on the subject of the mesh size of screening required to exclude various groups of flies. Davey and Gordon (1938), found the mesh size in use in West Africa too large to exclude all *Anopheles gambiae* Giles and *Anopheles funestus* Giles, and recommended 16 x 16 meshes to the inch and 28 S.W.G. wire. It is, of course, necessary to specify either the opening size, or the number of meshes to the inch and the gauge of the wire. There appear to be no published data with regard to the exclusion of blackflies, accordingly figures obtained by L. R. Pickering, Division of Entomology, Department of Agriculture, Ottawa, are given here in Table 2. On the basis of these, 20 mesh screening of 28 S.W.G. wire should be adequate for blackflies. According to Davey & Gordon it is the dorso-ventral dimension of the mesothorax which is important; the smallest value of this dimension found in 50 specimens of *S. venustum* was 0.0378 in., which is in accordance with the figures in Table 2. A number of specimens of common biting species of *Culicoides* were also measured, and the mesothorax of the smallest of these was 0.0169 in. deep. On this basis 40 mesh screening of 34 S.W.G. wire should exclude *Culicoides;* plastic screening is available in meshes considerably finer than this, and the cost is not prohibitive.

Self-closing devices on all entrance doors are useful. Outside privies hardly justify the application of the double door, but the lighting is usually so bad that biting is not serious even by mosquitoes. In more temporary camps some arrangement of portable screening for latrine accommodation is most desirable. A general purpose fly shelter is also of great value in maintaining the morale of men in camp

Table 2.—The penetration of blackflies through mesh of various sizes. Churchill, 1951.

No. of meshes per inch	Diameter of wire or filament, ins.	Dimensions of openings, ins.	Penetration
18 x 14	0.0110	0.0603 x 0.0445	10/30
19 x 16	0.0150	0.0475 x 0.0377	2/30
20 x 20	0.0110	0.039 x 0.039	2/30
20 x 20	0.0154	0.0346 x 0.0346	0/30
24 x 24	0.0104	0.0312 x 0.0312	0/30

under bad fly conditions. In forest country such a shelter can be readily and cheaply constructed with cheesecloth and staples and will remain serviceable for a full season. In tents, as in buildings, adequate screening and double doors are desirable.

When buildings and tents become invaded by flies, a hand spray pump, or an aerosol bomb is the best instrument for disinfestation. The aerosol bomb is the more convenient and the more expensive, it has the drawback of being useless once it is empty, even if abundant insecticide is at hand. There are still plenty of extremely badly designed hand spray pumps on the market, but a good one is as efficient as an aerosol bomb and much cheaper in use. For general purposes a pyrethrum DDT preparation is probably as good as anything. Needless to say the DDT must be omitted for use in any structure in which biological work with insects may be contemplated.

When, in spite of all methods of protection, the irritation of bites received begins to interfere with sleep, some treatment is called for. Any application for this purpose should have antiseptic properties to guard against secondary infection. Ammonia, washing soda, iodine, and more recently various ointments containing local anaesthetics are in common use. A preparation of this type recommended by Kingscote (In *litt.* 1951) is as follows: benzocaine 10%, salicylic acid 5%, methyl salicylate 2%, isopropyl alcohol ad 100%. Hoffman (1941) recommends the local application of chloroform. Very hot water is an excellent counter irritant for blackfly bites. With the recent emphasis which has been placed on the allergic nature of the reaction, has come the use of antihistamine preparations which have been well reported on (Gordon & Crewe, 1948).

INTERNAL PROTECTIVE PROCEDURES

The possibility of immunizing against the effects of the bites of blood-sucking flies has long aroused interest. That such a procedure would be practicable at least for blackfly bites, is strongly suggested by the observation that deaths of cattle from blackfly attack nearly all occur within the first 24 hours (Rempel & Arnason, 1947). The development of partial immunity to the effects of mosquito bites has been reported by Mellanby (1946) and has been confirmed by West (*In litt.* 1952) for northern *Aedes* species. As early as 1923 Georgevitch obtained a toxin from the heads of blackflies, to which an immunity was developed in animals. Although more progress has recently been made, and experimental antigens for blackfly bites are now available, there are two principal obstacles; first, the tremendous variation in the reactions of individual people to bites, and secondly, the lack of general agreement as to the cause of the reaction, which has already been discussed. It appears also that there is a similar variation in the reactions of a given person to the bites of individual flies of any particular species. These facts, and the absence of any absolute criteria or standards of comparison make it very difficult to evaluate progress in this field.

So long as immunizing techniques require a series of injections and give only short term results, they are unlikely to have much popular appeal; the bites of the flies will themselves render this service at less expense. For military and other special purposes, however, already existing techniques may prove useful.

Interest in dietary protection, or repellents for administration by mouth, first proposed by Ochman in 1911 (Graybill, 1914) has recently been revived. Attractive though this idea is, logical progress in this direction can only come after the factors responsible for the variation in attractiveness between different individuals, as distinct from the variation in severity of reaction, are better understood. It is perhaps necessary to draw a distinction here between repellents for oral administration, and the killing of biting flies by oral administration of an

insecticide, to circulate in the blood stream. This latter has been attended with more success, at least in veterinary applications, but although the two procedures overlap, it does not come within the scope of this article. A great many materials have been tested in this way, including many of the vitamins, sex and other hormones, volatile oils, alkaloids, and chemicals used as repellents on the skin (Kingscote, 1951). As yet, however, although Shannon (1943) found thiamin chloride effective, Wilson *et al.* (1944) were unable to confirm this, and at present there are no promising leads.

The psychological effects of biting flies present a more difficult problem than the physiological effects. Methods of protection against them have not been investigated, but the knowledge that adequate protection against the physiological effects is available is likely to prove helpful. Probably a contribution to the solution of this problem could be made through an indoctrination program on the lines indicated by Shelesnyak (1947). Through the normal educational media of films, lectures and pamphlets, some knowledge of, and above all interest in the biting flies could be imparted. Such knowledge should emphasize pleasanter aspects of the flies; the improbability of disease transmission, acquired immunity resulting from bites, and the small amount of blood taken. The more interesting gaps in our knowledge of these insects should be presented: the psychological threat is greatest to the incompletely occupied, and nobody with an interest in biting flies will be unoccupied when flies are around. Such mass amateur observations might contribute little to knowledge, but a great deal to morale. It seems likely that people should also be taught to control the removal reaction; there may be physiological as well as psychological grounds for this.

The threat of the biting fly can certainly be mitigated by the cultivation of an attitude of patient tolerance; by learning to accept these insects as an essential feature of an environment which offers compensations in other directions. Getting used to these pests and learning to live with them should be a part of the training of all who live in the north, since it is certain that despite aeroplanes and DDT, and anything that these may immediately foreshadow, the biting fly will be a feature of life in the north for many years to come.

Summary

Information on the factors which influence the attraction of northern biting flies, mosquitoes, blackflies, and tabanids to man and their subsequent feeding on his blood is reviewed. The effects of these insects on man and animals are discussed with some emphasis on the psychological effects which may be no less important than those of a physiological nature. Procedures to minimize this attraction and feeding, and to mitigate these effects are considered. It is concluded that the best protection is afforded by a judicious combination of partially protective clothing, including a fringed hat in preference to a net as head protection, with a standard repellent. A new type of container for insect repellents is proposed. These physical protections should be supported by a proper attitude of mind towards the insects, which can be inculcated by educational procedures.

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ARTICLES

EASTERN EQUINE ENCEPHALITIS IN THE UNITED STATES*

LESLIE D. BEADLE

Communicable Disease Center, Public Health Service, Federal Security Agency, Atlanta, Georgia

Although Eastern equine encephalitis (EEE) was not recognized as a distinct disease entity until 1933, there is good evidence that this malady has caused severe epizootics among horses and mules in the United States for at least 100 years. Many of the outbreaks formerly designated as cerebrospinal meningitis, blind staggers, and forage poisoning were no doubt caused by the virus of Eastern equine encephalitis. These included the outbreaks of 1847 in Long Island, New York (1), of 1902 in North Carolina (2), and of 1912 in Maryland, New Jersey, and Virginia (2, 3).

During the past 20 years, the Eastern type virus has caused outbreaks among horses, humans, and birds in various sections of eastern United States. At present this virus has been demonstrated in 17 states—all except Michigan, Missouri, Arkansas, and Tennessee located along the Atlantic seaboard or the Gulf of Mexico (4, 5, 6).

Outbreaks of Eastern Equine Encephalitis in the United States. Notable outbreaks (principally epizootics) of EEE during recent years include the following: (1) 1933 along the North Atlantic coast; (2) 1938 in New England; (3) 1939 along the South Atlantic coast; (4) 1941 in Texas; (5) 1942–43 in Michigan; (6) 1947 in Louisiana and Texas; and (7) 1949 in Louisiana and Arkansas.

The 1933 epizootic, centered along coastal and tidewater areas of Virginia,

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New Jersey, Delaware, and Maryland, was noteworthy not only because of its magnitude and severity—at least 1,000 horses were affected, with a mortality approximating 90 percent (7)—but also because isolations of virus from the brains of dying animals proved it to be a distinct disease (some of these first virus isolations were from Virginia cases) (3, 8, 9).

The 1938 outbreak of encephalitis in the New England states proved to be an epochal one, for it was learned for the first time that humans, especially children, are susceptible to the virus of EEE (10, 11, 12). An epizootic in horses preceded the human epidemic. The epizootic started in July in southeastern Massachusetts and later extended into Rhode Island and Connecticut. From July to late October, 381 cases were reported from these 3 states with a mortality approaching 93 percent (13).

A highly fatal encephalitis outbreak among children occurred in southeastern Massachusetts in August and September. Thirty-four cases were definitely identified, of which 74 percent terminated fatally (14). Of the nine survivors, at least six showed evidence of permanent brain damage (15). Seventy percent of the 34 cases were under 10 years of age.

An interesting epidemiological finding in connection with this outbreak was the occurrence of encephalitis among birds in the area. Unusual losses among pigeons and ring-necked pheasants were reported in the affected area, and EEE virus was isolated from a pigeon in Massachusetts (16), and from four ring-necked pheasants in Connecticut (17). Virus was also isolated from two pheasants in nearby New Jersey (18).

A mosquito survey was started in the affected area on September 19, 1938, but unfortunately a severe hurricane swept through New England 2 days later and destroyed many mosquitoes. When the survey was resumed in October, *Culex pipiens* was found to be the predominant species (14).

An extensive mosquito survey was conducted in Massachusetts the following year, and from the results of this study it was concluded that *Aedes vexans,* because of its distribution and abundance, was probably the chief vector of EEE in the area, but that salt-marsh mosquitoes—particularly *A. sollicitans* and *A. cantator* —might have been involved along the coast (19).

In 1939, the EEE virus presumably spread south along the Atlantic coast. In Florida, Georgia, and North Carolina, there were 524 reported cases among equines, with a mortality of 92 percent (20).

A relatively small localized epizootic of EEE in the vicinity of Brownsville, Texas, in 1941 was of particular interest because it constituted the first knowledge of the occurrence of the virus west of the Appalachian line, and the disease appeared in this area during April and May (4, 21). Usually EEE is a disease of summer and early fall.

When epizootics of EEE occurred in southwestern Michigan in 1942 and 1943, it became evident that this disease is not restricted to seaboard areas. Reported equine cases from Michigan for the 2 years totaled 102 and 367, respectively, with a mortality of 91 and 95 percent (22, 23). This area of Michigan is characterized by numerous lakes, ponds, swamps, and marshes (24, 25). It may be significant to note that a 1,000-acre bird sanctuary lies in the center of the epizootic area.

The largest proved EEE epizootic of record occurred in southern Louisiana and adjoining Texas in 1947. The official report of the Bureau of Animal Industry of the U. S. Department of Agriculture (26), gives 3,813 and 715 cases from Louisiana and Texas respectively; but a later report by the Department of Veterinary Science, Louisiana State University (27), lists 14,334 cases with 11,722 deaths for the State of Louisiana. The disease, which began in May in a parish on the Gulf coast line in southwest

Louisiana, spread north and west and finally involved southeastern Texas. The last cases were reported in October.

Accompanying this epizootic was a small outbreak in humans. From September 8 to October 23, 10 cases were definitely diagnosed as due to the Eastern type virus; 7 of the 10 died. All cases except 1 were in children, and 7 were under age 10 (28, 29, 30).

In 1949, Louisiana and Arkansas experienced an acute fulminating type of encephalitis which involved at least 1,700 equines (6). The mortality was reported as 98 percent. This epizootic, which started on the coast near the initial site of the 1947 outbreak, progressed northward to the middle of Arkansas.

The 1947 and 1949 outbreaks in Louisiana had certain characteristics in common, namely: (1) they started in an area where there are several bird refuges; (2) they occurred in districts with large areas of swamps, bayous, and rice fields; (3) the equine population was dense; (4) wading birds, such as egrets, and blackbirds were common; and (5) the mosquito population was high (31).

Reported Cases of Equine Encephalitis in Virginia. A total of 294 cases among horses and mules in Virginia was reported by the Bureau of Animal Industry during the 16-year period, 1935–1950. The number varied from 0 in 1941 to 50 in 1945. Encephalitis in equines has been reported from 24 counties in the state—all in the Coastal Plain physiographic province except Stafford and Spotsylvania in the Piedmont province. As far as I have been able to determine, no confirmed human cases of EEE have been reported in Virginia.

Epizootics in Pheasants. In addition to the previously mentioned episode of encephalitis in pigeons and pheasants that accompanied the 1938 outbreak in the northeastern part of the country, several EEE epizootics among pheasants have been reported in New Jersey, and one in Connecticut in 1951. Beaudette has reported 13 definite outbreaks of EEE in New Jersey pheasants from 1938 through 1946 (32). Examples of reported losses may be cited for two counties. In Burlington County, losses were 1,120 of 3,350 birds in 1943, 1944, and 1945. In Ocean County, deaths were 4,131 of 5,580 birds for the years 1945 and 1946.

The recent report of encephalitis in Connecticut (33) is of interest since it represents the first time that EEE has been recognized in the New England states since the 1938 outbreak. A study of the 1951 episode revealed that at least three game-breeding pheasant farms were involved and reported losses were as follows: On the first farm, 200 of 800 pheasants; on the second farm, 173 of 200 (the final 27 were destroyed by the owner); and on the third farm, 100 of 1,800 pheasants. EEE was identified by virus isolations from the brains of birds on the second and third farms and by virus neutralization tests from recovered birds on the first farm. The disease was first recognized on August 24, September 21, and the first part of October for the three farms respectively. During 1951, EEE infection was not recognized in horses or humans in Connecticut.

Mode of Transmission. It was suspected that equine encephalitis was insect-borne because of the prevalence of the disease during the insect season. Since EEE outbreaks were frequently associated with coastal and tidewater areas, some of the first experimental work on transmission included salt-marsh mosquitoes. In 1934 (34), Merrill and his co-workers found that EEE virus could be transmitted in the laboratory by *Aedes sollicitans* and *A. cantator;* also by the domestic mosquito, *A. aegypti.* In 1935, *A. taeniorhynchus* and *A. vexans* were added to the list of laboratory transmitters (35). When Davis (36), in 1939, demonstrated transmission of EEE virus by six species of *Aedes,* including *A. triseriatus* and *A. atropalpus,* but could not demonstrate conveyance by *Culex pipiens, C. salinarius, Anopheles punctipennis,* and *Mansonia perturbans,* many epidemiologists were convinced that *Aedes* mosquitoes were the principal vectors of the Eastern virus.

It should be stressed, however, that no species of *Aedes* has been found naturally infected with this virus. The ability of a species to transmit encephalitis under laboratory conditions and under field conditions may not be the same. Although salt-marsh mosquitoes have been incriminated as vectors, such mosquitoes are not known to occur in Michigan, where at least two epizootics of EEE have occurred.

Recently, Chamberlain of the CDC Virus Laboratory at Montgomery, Alabama, has found that the Eastern type virus can be transmitted experimentally by *Psorophora* mosquitoes: *P. ferox, P. confinnis, P. ciliata,* and *P. howardii*. Workers at the Virus Laboratory have also carried on experiments with *Culex quinquefasciatus*. These experiments indicate that few specimens retain virus for more than a few days after an EEE-infected blood meal. Although one transmission to a chick was accomplished after a mass feeding of "infected" specimens, it is not believed that *C. quinquefasciatus* could, under ordinary circumstances, be an important vector (37).

To date, only two species of mosquitoes have been reported as naturally infected with the virus of EEE. These are *Mansonia perturbans,* collected in Georgia in August 1948 (38), and *Culiseta melanura,* trapped in southeastern Louisiana in August 1950 (39). The epidemiological significance of these two species cannot be evaluated at present.

The Eastern type virus has also been isolated from chicken mites and chicken lice collected in Tennessee in August 1947 (5). In the laboratory, attempts to transmit EEE virus by chicken mites have yielded mostly negative results. Thus the role of their importance as potential vectors needs clarification.

Out of this somewhat spotty and confused picture, it is generally considered that mosquitoes are the usual vectors of the Eastern equine virus, but precise information as to genus or species is lacking.

In connection with the transmission of the EEE virus, the question arises as to what is the principal source of mosquito infection. Although both mammals and birds have been suggested as potential "reservoirs" of the viral agent, current evidence points to the theory that birds are the more important of these two groups. Studies show widespread infection in birds—mostly unapparent—with a high titer of virus in their blood stream for a short period of time. It is of interest to note that a wild bird—a purple grackle—which was later shown to have EEE virus in its blood was shot in June 1950 in a swamp in Louisiana (40), only a few hundred yards from the location where the naturally infected *Culiseta melanura* was collected in August 1950. Present knowledge of the epidemiology of EEE indicates that the basic cycle is mosquito-bird-mosquito, with man and horse as accidental entries into the infection chain. But the crux of the problem still remains: How is the virus carried over from one season to another? Birds are not considered long-term reservoirs of the virus since they contain circulating virus for only a few days, and they are not known to have recurrent viremias. It is hoped that the intensive investigations now under way will provide the answer to this unsolved problem.

Public Health Problem

One may well ask: Is EEE a public health problem? It must be recognized that this disease has been quite unimportant as far as numbers of humans affected are concerned, but it should be emphasized that the importance of this disease is not that of numbers. The importance lies in hysteria or panic which accompanies the unpredictable outbreaks. People are stricken with fear, and consequently publicity is tremendous. Health departments are bombarded with all kinds of questions, most of which they are unable to answer. In the wake of an outbreak, the public demands action. Thus it behooves all public health workers to be as well informed as possible on the epidemiology of the disease so that when an

outbreak does occur, the public can be properly informed.

CONTROL

On the basis of our present knowledge concerning the disease, the only feasible approach to the control of encephalitis is a program of prevention. Prevention of encephalitis consists of two principal avenues: (1) immunization; and (2) mosquito control. Vaccination is recommended as a prophylaxis for equines, but it is neither practical nor indicated for the general human population.

Mosquito control can hardly be justified solely on the basis of encephalitis prevention. However, it is frequently justified from the pest mosquito standpoint. Therefore, an encephalitis prevention program should be combined with nuisance mosquito control activities—by the community and by individuals—so that the work would be justified economically. In view of our lack of precise information concerning the vectors of EEE, the control program should include virtually *all* species of mosquitoes. In summation, mosquito control for the community and protection against mosquito bites for the individual are the most reasonable prophylactic measures against this dread disease.

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THE EFFECTS OF DESICCATION ON THE EGGS OF *ANOPHELES QUADRIMACULATUS* SAY

L. KARTMAN and R. P. REPASS

From Communicable Disease Center, Public Health Service, Federal Security Agency, Atlanta, Georgia.

Anopheline eggs apparently have been found to be fairly resistant to desiccation under experimental conditions. Mayne (1926) reported survival of *Anopheles quadrimaculatus* eggs for as long as 16 days, and survival of *A. crucians* eggs for 21 days when subjected to drying mud. Stone and Reynolds (1939) obtained larvae of *A. punctimacula, A. albimanus,* and *A. aquasalis* from Canal Zone mud which had been devoid of standing water for about one month. Deane and Causey (1943) found some *A. gambiae* eggs able to survive for 18 days in drying sand. Darrow (1949), in a series of critical studies, showed that eggs of *A. quadrimaculatus* had to be kept moist for between 0.2 and 0.3 of the total period of embryonic development in order for them to resist desiccation. She further suggested that eggs on a dry substratum would continue to develop provided the relative humidity was 100 percent.

The present studies were undertaken

to determine if *A. quadrimaculatus* ova could withstand periods of drying in Arkansas rice fields.

Materials and Methods. Crowley type alluvial clay-loam was collected from a delta breeding area near Helena, Arkansas, and silty clay-loam was collected from a Stuttgart rice-field breeding area. Both types of soil were dried and pulverized for uniformity and placed in small aluminum funnels, provided with filter paper liners, to within about ⅜ inch of the top. The spout of each funnel was tightly corked and the funnel filled with tap water. These funnels were then placed in cages containing gravid *Anopheles quadrimaculatus* females collected from specific locations and allowed to remain overnight. The next morning funnels with eggs were removed from the cages, the corks in the funnel spouts withdrawn, and the water allowed to drain so that the eggs could settle on the moist soil surface. All funnels were numbered and placed in racks and the soil in them allowed to dry spontaneously. Eggs on the soil surface in each funnel were counted; eggs on the funnel lips or sides were removed. At approximately 24-hour intervals after desiccation began, funnels were flooded with tap water and counts made of hatching on a 24-hour basis. All experiments were conducted in an inside room without special regulation of temperature and humidity.

Controls for these studies consisted of: (1) funnels on which *Aedes aegypti* oviposited that were flooded after *Anopheles quadrimaculatus* eggs failed to hatch; (2) funnels of eggs from appropriate *quadrimaculatus* strains which were not drained but the eggs allowed to hatch normally—*quadrimaculatus* control No. 1; (3) funnels into which samples of eggs from all experimental funnels were placed and then allowed to hatch normally—*quadrimaculatus* control No. 2.

Data and Discussion. A total of five tests was conducted in which the Q-1 colonized strain of *A. quadrimaculatus* was used each time, the Delta strain on three occasions, and the rice-field strain only once. Table 1 summarizes all of the pertinent data for these tests.

These data suggest that eggs of the colonized strain of *quadrimaculatus* were the least resistant to desiccation. This appeared to be true whether delta or rice-field soils were used or whether the temperature reached maxima of 80° F. or 90° F. The eggs of wild-caught *quadrimaculatus,* whether from delta or rice-field breeding areas, appeared quite similar in their resistance to drying. It is of interest that the initial hatch of eggs from wild-caught mosquitoes was almost always below that of the Q-1 eggs. However, fewer Q-1 ova hatched subsequently than ova from the wild-caught strains.

Actually, the data are too meager to warrant drawing definite conclusions. They do suggest that a drying period of approximately one week would probably be sufficient to kill a majority of wild *quadrimaculatus* eggs on rice-field soils. Similar results were obtained by Hill and Cambournac (1941), who found that drying of Portuguese rice fields for periods of seven days, followed by flooding periods, would reduce anophelines by over 80 percent. The irrigation practices of planters in the Arkansas rice-growing region are such that *quadrimaculatus* have breeding water available throughout most of the growing season. However, depending upon the individual planter, there is usually at least one drainage period during the summer when the soil is permitted to dry until firm enough to be walked on (Nelson, 1944). This is undoubtedly sufficient to kill *quadrimaculatus* eggs.

SUMMARY

1. Observations were made on the ability of eggs of *Anopheles quadrimaculatus* obtained from different sources to survive desiccation under experimental conditions.

2. The data suggest that eggs of the colonized (Q-1) strain of *quadrimaculatus* were the least resistant to desiccation.

3. It is suggested that a drying period of about one week would probably be

TABLE 1. Effect of experimental soil desiccation on hatching of *Anopheles quadrimaculatus* eggs

Exp. No.	Strain	No. of eggs	Soil type	Temperature Range °F.	Relative humidity range %	Percent of eggs hatching Desiccation period in hours 48	72	96	120	144	168	192	216
	Q-1	3917	Delta	78-80	35 65	78	69	53	16	2	0	0	—
1	*quadrimaculatus* control #1	600	"	"	"	75	—	—	—	—	—	—	—
	aegypti control	44	"	"	"	—	—	—	—	—	—	—	75
	Q-1	951	Delta	78–82	35–68	60	71	25	2.7	0	0	0	0
2	*quadrimaculatus* control #1	80	"	"	"	60	—	-	—	—	-	—	—
	quadrimaculatus control #2	111	"	"	"	61	—	—	—	—	—	—	—
	aegypti control	109	"	"	"	—	—	—	—	—	—	65	—
	Q-1	165	Rice-field	79–87	28–68	55	27	5	0	0	0	0	0
3	Delta	2000	"	"	"	23	40	27	21	11	2	0.7	0
	Rice-field	784	"	"	"	56	35	30	18	7	13	0	0
	quadrimaculatus control #1	260	"	"	"	50	—	-	—	—	—	—	—
	quadrimaculatus control #2	254	"	"	"	62	—	—	—	—	—	—	—
	aegypti control	998	"	"	"	—	—	—	—	—	—	—	84
	Q-1	556	Rice-field	76–89	38 79	62	51	4	2	1	0	0	—
4	Delta	932	"	"	"	31	21	37	8	39	0	1	—
	quadrimaculatus control #1	254	"	"	"	46	-	—	—	—	—	—	—
	quadrimaculatus control #2	180	"	"	"	64	—	—	—	—	—	—	—
	aegypti control	992	"	"	"	—	—	—	—	—	—	—	73
	Q-1	950	Rice-field	78–91	41–66	73	61	40	4	0.4	0	0	—
5	Delta	2331	"	"	"	51	59	45	41	7	11	0	0
	quadrimaculatus control #1	266	"	"	"	58	—	—	—	—	—	—	—
	quadrimaculatus control #2	213	"	"	"	60	—	—	—	—	—	—	—
	aegypti control	661	"	"	"	—	—	—	—	—	—	—	87

sufficient to kill a majority of wild *quadrimaculatus* eggs on rice-field soils.

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MOSQUITO CONTROL ON ARMY POSTS IN THE FAR EAST

A. W. MORRILL, JR.,[1] A. N. DANDOY,[2] M. S. JOHNSON,[3] J. F. POOLE,[4] and R. H. VINCENT [5]

Mosquito control at all fixed Army installations in Japan, Okinawa, the Philippines, Guam and Korea is a responsibility of the Post Engineer, as it is in the United States. Utilizing local civilian employees, trained by civilian entomologists in the Corps of Engineers, crews have been established and control operations placed upon regular schedules. The work was supervised by American civilian and enlisted men, by locally employed entomologists and by local crew members who demonstrated abilities of such calibre as to warrant their being given further specialized training and higher responsibility. Close coordination has been maintained between the Engineer organizations and the Army Medical Service, whose survey and control units conduct all operations in combat areas, and whose survey and laboratory units under the direction of Medical Service entomologists have been an integral part of the program.[6] In 1946, most of these control units of the Army Medical Service had been rapidly deactivated and until the local civilian crews could be recruited and trained, operations were often quite unsatisfactory. However, in every area, both the local employees and the American civilians and enlisted men proved to be interested in the work, energetic and capable, and soon developed a high morale and a very considerable efficiency.

Principal Species of Mosquitoes: The principal disease-bearing mosquitoes and their primary breeding places were as follows: *Anopheles hyrcanus sinensis*—(rice paddies); *Anopheles maculatus*—(streams); *Anopheles minimus flavirostris*—(clear streams); *Anopheles subpictus*—(swamp and mud holes); *Aedes albopictus*—(scrap yards, flooded ruins, water containers); *Culex quinquefasciatus* (*fatigans*)—(stagnant water, water con-

[1] Formerly Entomologist, GHQ, Far East Comd.; now with Eng. Res & Dev. Lab. Ft. Belvoir, Va.

[2] Formerly Entomologist, Phil. Base Comd.; Manila; now Ryukyus Cmd.

[3] Entomologist, Hq & Sv Cmd, Tokyo, Japan.

[4] Entomologist, Ryukyus Cmd; Okinawa.

[5] Formerly Entomologist, Marianas-Bonin Cmd; Guam, now Asst. Chief, I & R Sect., OCE, Wash., D. C.

[6] Especially invaluable aid has been supplied by Lt. Col. S. C. Dews, 8th Army, Lt. Col. J. E. Webb, Jr., Brooke Army Med. Ctr., Lt. Col. S. O. Hill, Brooke Army Med. Ctr., Capt. H. C. Barnett, 406th MGL, Tokyo, Japan, & Dr. William Suyemoto, 406th MGL, Tokyo, Japan.

tainers); *Culex pipiens*—(water containers, paddies, stagnant water); *Culex tritaeniorhynchus* — (water containers, early season paddies). In addition, *Anopheles limosus* breeding in paddies in the Philippines, and *Aedes pandani,* breeding in pandanus bracts and other standing water in the boondocks or jungle on Guam, were pests of considerable importance, although *pandani* rarely entered houses.

Knowledge of the importance, interrelations and habits of these various mosquitoes was greatly aided by the advice and assistance of entomologists native to or long resident in the areas.[7]

Quite diverse problems of mosquito breeding and habits were encountered in the various areas. In the Philippines, the only lowland vector of malaria is *Anopheles mininus flavirostris,* which breeds almost solely in clear, uncontaminated streams. *A. maculatus,* breeding in both streams and paddies and implicated in the rare transmission occurring in the mountains, does not breed in the lowlands. *Anopheles hyrcanus sinensis,* a rice paddy breeder which is the carrier of malaria in Okinawa, Japan and Korea, while numerous in the Philippines, is not considered to be a carrier there. The problem of malaria control, therefore, centered upon treatment of all streams in or around the Army and Air Force areas. Even extremely small tributaries, many of which were completely hidden under the relatively short, thick-growing *cogon* and the pampas-like *talahib* bunch grasses, were capable of producing dangerous populations of *minimus.*

In Guam in 1944, an epidemic of dengue caused a brief but energetic eradication campaign which eliminated *Aedes aegypti* from the island. It has not reappeared. However, in 1947, it was discovered that, since the war and presumably by means of insufficiently treated aircraft, two new disease vectors had been introduced to Guam. One, *Aedes albopictus,* the very efficient dengue carrier of the Philippines, breeds so much more indiscrimately than *aegypti* that control has been vastly more difficult. It is found in all untreated areas where water stands in old tires, car bodies, junked machinery, war-time scrap, household water storage tanks, or discarded tin cans. The other, *Anopheles subpictus,* an inefficient but potential malaria carrier from the Celebes, breeds in a wide variety of types of standing open water. This natural standing water is relatively scarce. The encephalitis carrier, *Culex quinquefasciatus,* breeds in loosely-covered drainage pits under community wash houses as well as in rainwater storage drums, old tires, discarded equipment, etc., and its control is almost entirely one of community sanitation. The only other important mosquito, *Aedes pandani,* is a vicious biter, but rarely goes far from the boondock or jungle made up of pandanus, coconut, papaya, jack-fruit, and vines, even more rarely enters houses, and carries no disease.

In Okinawa and the whole Ryukyus, the malaria vector, *Anopheles sinensis,* breeds in paddies and the encephalitis carriers, *Culex quinquefasciatus* and *C. tritaeniorhynchus,* also breed in paddies but more especially in discarded tin cans, scrap vehicles, tires, cisterns, privies, drains, and similar places.

South of Okinawa, both *Anopheles minimus* and *A. sinensis* are found in slowly-flowing paddies and streams. *Culex quinquefasciatus,* the supposed vector of encephalitis, and *Aedes albopictus,* the dengue vector, breed in cisterns, ditches and *benjos* (privies). Dr. S. Ohama of Yaeyama Retto discovered *A. sapperoi* breeding in rivers in Ishigaki in far larger numbers than have ever been found in Okinawa, from which it was described by Bohart, but where it has not since been recaptured. Because of its abundance and other apparent indices, Dr. Ohama believes it to have been a principal vector of

[7] Notably Dr. Francisco Dy, WHO, Manila; Mr. Fernando Gutierrez, Univ. of Phil.; Dr. A. Fiercito, Phil. Bur. Health; Mr. R. Urbino, Phil. Bur. Health; Dr. T. Koïima, Tokyo Univ.; Dr. K. Shiraki, FSS, Tokyo; Dr. S. Ohama, Health Officer, Yaeyama Retto (Ryukyus).

malaria in Yaeyama prior to its control. His efforts at control of the mosquito were so successful, however, that malaria dropped to a near-vanishing point and he was unable to complete his studies.

In Japan, malaria is carried by *Anopheles sinensis,* but it has been a disease of minor importance. On the other hand, encephalitis carried by *Culex pipiens* and *C. quinquefasciatus* has been a very grave problem. Potential breeding sources are so numerous that some authorities have felt that attempts at larval control would be useless. Breeding occurs in *benjos,* or privies, in ditches, in bamboo stumps, or posts, in cemeteries and in broken shards and rubble. With the advancing clean-up and restoration of Japan to pre-war standards of neatness and higher ones of sanitation, the roadside ditches now constitute the principal breeding source. Inasmuch as nearly every street and road, save only the ones in the center of the largest cities, is bordered with such ditches, either uncovered or loosely covered with boards or concrete slabs, it will be seen that this one source is at present more than enough to require a vast amount of effort to be expended in order to secure larval control. Korea presents a problem which is a combination of Japan, with its urban breeding places and Okinawa with its extensive paddy breeding, plus the exigencies created by the unstable political and military situation.

In order to secure control in military installations, which are often small and are almost always surrounded by large and complex breeding areas, an interrelated program of survey, regularly recurrent treatments and coördination with civil programs was developed. Surveys were usually carried out by Medical Department personnel, some of them civilians formerly in Philippine Scout Malaria Survey Detatchments, and these surveys were directed toward determining not only the sites where breeding occurred but also the weekly population levels, which would indicate the effectiveness of control applications. In some areas, as in Guam, no Medical Department detachments existed and these civilians formerly in the Medical Department units were employed by the Corps of Engineers. In Japan, there were but two medical units and survey was useful only to indicate breeding sites; population levels were determined by local Engineer employees trained by the entomologists. In Korea, on the other hand, the Medical Department units did little survey but provided supervision for civilian Post Engineer employees organized as control teams.

Since installations were small, permanent larval breeding control was usually secured in the military area by the very construction of the installation itself and the establishment of its primary drainage. This however, was a minor part of the potential breeding area in most localities and the control problem was therefore largely one of preventing entry of mosquitoes originating outside the military enclosure, and of destroying those which managed to penetrate the barrier. Commencing with the eradication of breeding in the military area, control of adults was initiated with the residual spraying of building interiors. These were sprayed at intervals of not over 60 days during the warm weather, which ranged from a period of 3 months in Hokkaido to the year round in Guam and the Philippines. A residual treatment of DDT was applied with a flat spray to walls and ceilings, paying particular attention, of course, to areas behind doors, cabinets, and draperies and to the under surfaces of beds, chairs, desks, and tables. Screen doors and windows were given more frequent applications, because of fly control, usually at about 30-day intervals. Screening was required on all housing and recreation buildings.

Sprays and dusts were used to apply residual coatings to open buildings, such as bath houses, stables and sheds, both in the military area and in farm and urban areas closely surrounding the military enclosures. Fog generators, capable of producing sustained wet fogs of approximately 30 micron particle size, and power dusters were used extensively to place a

residual coating on foliage and shrubbery and thus form a protective barrier zone to the migration of adult mosquitoes. These were found to be very effective, especially the dusts, which effectively penetrated shrubbery and tree plantings and among buildings and withstood weathering for a week or ten days. Even outdoor theatres such as the amphitheatre in Hibiya Park in downtown Tokyo and the Meiji Park Stadium were effectively protected.

FIG. 1. Clouds of DDT dust, drifted through vegetation and back-yards of occupation homes and Japanese areas adjacent to Occupation housing units, greatly reduce populations of flies and mosquitoes which are potential invaders of military installations.

Breeding places in regions contiguous to but not under the control of the military were also treated in conjunction with or by permission of the local authorities. These treatments were usually sprays or dusts applied by hand-operated equipment carried by individual operators who sought out ditches, privies, drains, rubble, rubbish, paddies, and streams. The regular scheduling of treatments of all areas by the Post Engineer crews is believed to have been a major factor in creating the almost complete freedom of many military enclosures from mosquitoes of all sorts as well as a factor in the economy of the operations. Disease rates among military personnel dropped to very low levels with the progressive efficacy of the control. Among surrounding populations in Japan and Okinawa, where community control was practiced, similar though less marked reductions in disease prevalence occurred.

On Okinawa, and occasionally in Japan, off-post operations covered extensive rice paddies, and power equipment was often utilized; in Okinawa, aircraft dispersal was especially beneficial, dust being used during the latter part of the season when penetration of mature rice plantings with oil sprays was impossible. Like the interior residual applications, these outdoor treatments were scheduled on a regularly recurrent basis, being usually applied at 10-day intervals. Both with air and ground equipment a dispersal of 1–5 pounds of dust per acre was attempted and surveys showed that both adult and larval populations were either greatly reduced or eliminated.

A number of considerations imposed severe restrictions on the use both of ground power dispersal equipment and aircraft for insecticiding. In Japan, because of silk culture, promiscuous and wide-spread insecticidal applications could not be permitted and use of aircraft was therefore automatically proscribed. In Guam and the Philippines natural breeding areas were largely inaccessible to sprays from aircraft and in Okinawa, Japan, Korea, Guam, and the Philippines alike, urban areas were more productive of mosquitoes in terms of larvae per acre than rural ones and these places of course were unsuitable for treatment by aircraft. On the other hand, in certain locations in the Philippines and in Okinawa, the use of liaison-type airplanes and helicopters was very useful and at least some of the areas could not feasibly have been treated otherwise.

In the Philippines, in and around Clark Air Force Base and the Ft. McKinley Philippine Scout General Hospital in Manila, lengthy streams and the Pasig and

Bamban Rivers, where the banks were open, were sprayed from the air, using small, single-engined liaison, or L-5 planes which followed the stream courses at low altitude and secured very effective control for ten-day to two-week periods. In Okinawa, during and immediately following the combat period, aerial spraying was done by means of C-47's. The control, at first apparently good, gradually became very poor and in addition damage was done to crops and trees and the balance of nature seemed to have been considerably upset. By use of the small, low-flying planes and regularly assigned pilots, it has been possible to keep anopheline populations so low as to be inappreciable in large paddy areas where the use of American power equipment is precluded by the lack of roads and even the small, more-maneuverable Japanese power equipment could not easily be used.

As has been said in discussions of each area, the mosquito control problems in the Orient are not radically different from or impossibly more severe than those in the United States. In many places, such as much of the Philippines and the southern Ryukyus, complete control seems well within the bounds of possibility. While the work done by Engineer crews outside of military boundaries was not done for the protection of the neighbors, it did have that incidental effect, and apparently encouraged many householders, in all areas, to undertake personal measures.

In Japan, with habits of neatness and of community effort and with the relatively well-defined breeding locales, the mosquito population could be brought to insignificant levels in cities and villages and even in many farm areas. Based upon the results in Army areas, it seems possible that general mosquito control could be relatively effective there if measures were applied only to public ditches and if individual home owners were taught and encouraged to treat and to reduce the breeding areas in their own yards. The chemicals are presently abundant and fairly cheap and the Japanese have a long tradition of community responsibility. While no miracles are to be expected, the Japanese investigators do not feel that the situation is hopeless and there is a growing interest on the part of the average householder in applying for himself the local measures which the Army has found so effective.

In addition to local mosquito control teams of varying degrees of efficiency, the Japanese Government has for two seasons undertaken a fairly extensive program of dusting with BHC and lindane for the control of the newly introduced fall webworm, called *Amerika hi-tori,* or American Moth. A small and easily maneuverable power duster was utilized in dusting, and overdusting rather than economy of dust was the rule. It would appear on the basis of population counts made by Medical Department entomologists, that this general and heavy dusting may have had some considerable side effect in reducing the mosquito population. No resistance to either BHC or DDT was apparent at the close of the 1951 season.

FIG. 2. Duster and Fog Generator used in Japan, Okinawa and Korea. Capacity 50 lbs. dust, 35 gallons oil/hr.

SUMMARY

In summary, the problem of preventing mosquitoes from infesting military installations centered upon the fact that the installations were relatively small and the surrounding mosquito breeding areas large. Surveys showed that disease-bearing mosquitoes bred in a wide diversity of places, but that the largest numbers came from water standing in ditches, war rubble, carelessly discarded cans, and outworn equipment and drainage pits. Rice paddies were less important than would be supposed, except on Okinawa where they supplied the malaria carrier, and clear streams were the chief locale of malaria mosquito breeding in the Philippines.

Control commenced with clearing all breeding from the military enclosure, followed by regular and frequent applications of residuals to all inhabited buildings to prevent entry and harborage of adult mosquitoes. Residual adulticides, notably dusts, were utilized to create barrier zones in foliage surrounding the installations and to leave adulticidal deposits in animal shelters, sheds, outside baths and privies and under eaves of buildings, gates, and walls. Surrounding breeding sites were treated with larvicides as far as possible, especially nearby privies, ditches, scrap heaps and paddies. Paddies were treated with dusts after the rice became well-grown because of the greater penetration. Power equipment was used in some cases for adulticiding and larviciding, and, where it was suitable, small, low-flying aircraft were routinely utilized. These were not always suitable because of silk-culture or inaccessibility of breeding places.

Control of mosquitoes in all areas, in view of the success on military installations, seems to be quite feasible and some progress has already been made in Japan and the Ryukyus. No resistance to DDT or BHC was apparent to the end of the 1951 season.

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ASSOCIATION NEWS

REPORT OF THE AMCA GOOD NEIGHBOR CLUB

February 15, 1951 to February 15, 1952

Total cash collected before February 15, 1951: $292.92; also a quantity of miscellaneous publications on entomology and mosquito control.

Cash collected February 15, 1951–February 15, 1952, H. A. Crandell, Toledo, Ohio, $3.00; R. J. Brady, Jersey City, N. J., $1.00; J. T. Degnan, Jersey City, N. J., $1.00; Lester Smith, Metuchen, N. J., $2.00; A. J. Rogers, Gainesville, Fla., $2.00; L. S. Henderson, Washington, D. C., $1.00; T. D. Mulhern, Fresno, Calif., $10.50; H. L. Trembley, Bethesda, Md., $3.00; E. C. Winkler, San Mateo, Calif., $4.00; S. Thomas, Indio, Calif., $5.00; T. M. Sperbeck, Yuba City, Calif., $5.00; T. D. Mulhern, Fresno, Calif., $8.00; Bureau of Vector Control, Berkeley, Calif, $3.00; Julius Hyman & Co., Denver, Colo., $100.00; C. W. Hackett, Berkeley, Calif., $5.00; H. H. Stage, Washington, D. C., $10.00; J. H. Kimball, Santa Ana, Calif., $1.00; J. G. Shanafelt, Jr., Santa Ana, Calif., $1.00; D. C. Crandall, Durham, Calif., $2.00; P. J. Gillette, Berkeley, Calif., $2.00; Gordon Edwards, San Jose, Calif., $1.00; Carl D. Duncan, San Jose, Calif., $1.00. Total past year, $171.50; total to date, $464.42.

Receipts: Book and Periodicals—February 15, 1951 to February 15, 1952: George E. Powers and Union County Extermination Commission: *Mosquitoes of New Jersey* by T. D. Headlee, 34 copies; Lester Smith and Middlesex County Mosquito Extermination Commission: *Mosquitoes of New Jersey* by T. D. Headlee, 6 copies; Salvaged from USDA attic, *Journal Economic Entomology,* 40 copies; *Annals Entomological Society of America,* 20 copies; Helen Louise Trembley, Miscellaneous scientific publications, 25 copies; H. H. Stage, 1949 and 1950 Volumes *Mosquito News,* 8 copies.

Dispersals: Two volumes (8 numbers) of Mosquito News have been sent to each of the following libraries. Value $60.00: Taiwan Malaria Research Institute, Taipet, Formosa; Taiwan Agricultural Research Institute, Taipet, Taiwan, Formosa; South African Institute for Medical Research, P. O. Box 1038, Johannesburg, Union of South Africa; Institute of Hygiene, Manila, Philippines; Skikoku Entomological Society, Matouyama Agricultural University, Skikoku, Japan; Institute of Hygiene, Oslo, Norway.

A year's subscription has been paid for each of the following individuals. Value $95.00: Dr. Percy Wright, Bermuda Health Department, Witu, Warwick East, Bermuda; Dr. Erich W. Kirchberg, Robert Koch Institute, Correonplatz 1, Berlin, Dahlen, Germany; Dr. H. T. Socparmo, Chief, Malaria Control, Djalan Diponegori 69, Djarkarta, Indonesia; Dr. Jaswant Singh, Chief, Institute of Malaria, 22 Alipore Road, New Delhi, India; Dr. Gerardo L. Adan, 27 Gomez Street, Dagupan City, Philippine Islands; Dr. Mirza Ali Ahmad, 100 Aga Sadek Road, P. O. Ramna, Dacca, Pakistan; Dr. Francisco J. C. Cambournac, Avenida Dr. Cambournac, No. 4, Sintra, Portugal; Dr. Augusto Corradetti, Instituto Superiore di Sanita, Viale Regina Margherita 299; Roma, Italy; Prof. C. Y. Chow, Insect-Borne Disease Control Training Center, Kurunegala, Ceylon; Dr. Tah-Neng Chen, Taiwan Agricultural Research Institute, Taipet, Taiwan (Formosa) China; Dr. J. D. Campbell, Turoa, Rarotonga, Cook Islands; Dr. Aaron Amramy, Director, Division of Sanitation, Ministry of Health, Jerusalem, Israel; Dr. M. A. C. Dowling, Director, Malaria Eradication Scheme, Floreal, Mauritius; Dr. D. C. Geijskes, Entomologist, Surinam Agricultural Ex-

TOP: Group of AMCA members in lobby of Hotel Utah; includes five presidents of the Association and other prominent members, as follows: (Left to right) Stutz, L. Smith, Rees, Hirst, Mulrennan, R. F. Peters, Lindquist, Carpenter, Clarke; *front row,* Stage, Dorer, Gray, Twinn.

BOTTOM: Tommy Mulhern, retiring secretary, and Mrs. Mulhern, at the Hotel Utah after the presentation of the clock which was given him as a token of appreciation and esteem by the members of the AMCA.

TOP: On the evening of March 25, 1952, during the AMCA convention in Salt Lake City, officers of the Association took part in a television broadcast from KDYL. From left to right they are Dr. F. C. Bishopp, Vice-President-elect; Dr. C. R. Twinn, President-elect, and Dr. Don M. Rees, President. The announcer, Mr. Richardson, is holding a glass containing mosquito larvae. In the larger container are mosquito-eating fish, *Gambusia affinis*.

BOTTOM: AMCA Field Tour group picture at Copper Club, Magna, Utah, after visit to Kennecott open pit copper mine at Bingham. (Photographs by Ed Smith).

periment Station, Paramaribo, Surinam, South America; Dr. Hamdi Acan, Istiklal Caddesi No. F 9, Ismit, Turkey; Dr. Abdel Aziz Bindari-Bey, 15 Rashdan Street, Orman, Giza, Cairo, Egypt; Dr. John W. Field, Institute for Medical Research, Kuala Lumpur, Malaya; Dr. George Giglioli, P. O. Box 405, Georgetown (Demerara) British Guiana, S. A.; Dr. Harold P. Lyon, Harbel, Liberia, West Africa.

Total value of Mosquito News donated by Good Neighbors, $155.00. Balance on hand, February 15, 1952, $16.50.

Forty copies of Dr. T. D. Headlee's "Mosquitoes of New Jersey" and the available numbers of the Journal of Economic Entomology, the Annals of the Entomological Society of America, and several miscellaneous publications have been sent also to the six libraries mentioned above as well as to the following: Dr. B. K. Rao, 390 Vithalewadi Narayanguda, Hyderabud (DN) India; Dr. Jaswant Singh, Malaria Institute of India, 22 Alipore Road, Delhi, India; Library, Powley & Co., Durban, Natal, South Africa; Etablissements Osterrieth, S. A., 64 Longue rue Neuve, Antwerp, Belgium; Library, Charles Gouldson, Ltd., Colombo, Ceylon; Dr. Hans Oberlaender, Apartado Aereo 4153, Bogotá, Colombia; Aktieselskabet Kemidroga, 26 Sct. Annae Plads, Copenhagen K., Denmark; Velez & Cia, Guayaquil, Ecuador; Veillon y Cie, Bôite Postale 384, Cairo, Egypt; J. G. Hirst, Gollin & Co., Ltd., G.P.O. 199, Auckland, New Zealand; Library, Tokio University, Tokyo, Japan; Library, Kyoto University, Kyoto, Japan; Library, Tohoku University, Sendai, Japan; Agricultural Experiment Station, Paramaribo, Dutch Guiana, South America; Université de Gand, Ghent, Belgium; Université Catholique Louvain, Louvain, Belgium; Librairie G. Van Campenhout, Bruxelles, Belgium; Statens Seruminstitut, Kobenhavn S, Amager Boulevard 80, Copenhagen, Denmark; Université Egyptienne, Cairo, Egypt; Dr. S. Madwar, Research Institute, 10 Sh. Kasr El Aini, Cairo, Egypt; Bureau of Science, Manila, Philippines; École de Medicine, Teheran, Iran; Institute of Tropical Hygiene, Amsterdam, Netherlands; Naval Med. Research Univ. #3, American Embassy, Cairo, Egypt; University College, Dublin, Eire; University College, Galway, Eire; University of Liverpool, Liverpool, England; London School of Hygiene & Tropical Medicine, London, England; British Mosquito Control Institute, Hayling Island, Hants, England; Prof. P. A. Buxton, London School Tropical Medicine, London, England; The Science Museum, South Kensington, London S. W. 7, England; Malaria Laboratory, Horton Hospital, Epsom, England; Dr. Juan José Alcocer, c/o Direccion General de Ganidad, San Salvador, El Salvador; Revue du Paludisme et de Med. Trop., Paris IV i, France; Doyen de la Faculté de Medicine, Université de Strasbourg, Strasbourg, Alsace, France; Royal College of Medicine, Baghdad, Iraq; W. S. STEM to Thailand, c/o American Consulate, Chiengmai, Thailand.

These publications have been stamped "With the compliments of the Good Neighbor Club, American Mosquito Control Association." All transportation charges have been borne by the International Exchange Service of the Smithsonian Institution of Washington, D. C.

The Good Neighbor Club has received a few subscriptions to Mosquito News and several letters from libraries and others acknowledging our contributions. Mrs. Ernestine Thurman, a member of this Committee now in Thailand, writes: "Thailand needs all available assistance from AMCA. Any effort on your part will not be wasted. The workers in malaria control are eager for information, literature, equipment, and encouragement. It was quite a blow to find a total void of natural history collections in the magnificent, spectacular national museum in Bangkok." Tommy Mulhern writes: "I have entered into the spirit of your Good Neighbor Club by paying up back dues of C. Y. Chow, our good friend who is in Formosa. You may not know it, but because of inflation, it costs Dr. Chow

almost a week's salary for a stamp to write us. If someone else wants to participate in like fashion, they might take care of back dues of Teh-Nevg Chen, who is also in Formosa and whose account remains unpaid from 1948." A bundle of publications sent to Japan were acknowledged by Don J. Pletsch: "Subject literature has been presented as a gift from the American Mosquito Control Association to the Library, Infectious Diseases Research Institute, 39, 1-Chome, Shiroganedaimachi, Shiba, Minato-Ku, Tokyo, Japan. I would recommend this institution as a worthwhile repository for any additional literature which might be forwarded through action of the Association." A pleasant surprise was afforded us by a personal visit of Dr. Erich W. Kirchberg, scientific member of the Robert Koch Institute, Berlin, Kahlem, Germany. Through Colonel Ralph W. Bunn's recommendation a package of Mosquito News was sent Dr. Kirchberg about a year ago along with Dr. Headlee's "The Mosquitoes of New Jersey." Dr. Kirchberg wanted to thank the Good Neighbor Club in person for the books sent him. When he was in the United States for a few weeks and had American dollars, he took out a 2 years' subscription to Mosquito News. Alicia Izquierda, Librarian of the Biblioteca de la Escuela de Ciencias Medicas, Universidad de Chile wrote: "We have received the book on New Jersey Mosquitoes and other publications from the American Mosquito Control Association. As you probably know our library was partially destroyed by fire in December 1948. We appreciate your donation very much and it will help to rebuild our collection and to consolidate our countries' friendship."

We have received a number of additional letters of appreciation for our Goodneighbor efforts.—Dorothy McCullough Lee, Ernestine B. Thurman, Myrtle E. Rueger, Emma M. Vickers, Helen Louise Trembley, Helen Sollers, Harry H. Stage, Chairman Good Neighbor Club.

NEWS AND NOTES

AN EARLY RECORD OF THE USE OF PARIS GREEN AS A MOSQUITO LARVICIDE. W. V. King, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine.*

The discovery of paris green as a mosquito larvicide is usually credited to M. A. Barber and T. B. Hayne from the work reported in their article "Arsenic as a Larvicide for Anopheline Larvae" published in the Public Health Reports, vol. 36, pp. 3027–3034, December 9, 1921.

Recently I have found in my files an old newspaper clipping from the New Orleans *Times Picayune* of February 16, 1916, containing a letter to the Editor by B. W. Marston, Sr., dated February 9, 1916, describing the effective use of paris green for destroying mosquito larvae in water barrels. The letter was printed under the heading "Mosquitoes" and is quoted in full as follows:

"Ninock, La., Feb. 9, 1916

"To the Editor of the Times Picayune:

"I have read your editorial on the mosquito with interest. When I was a member of the Crop Pest Commission of this state, I noticed that the water left over in the wash tubs, every week in warm weather, was literally filled with wiggletails—the larvae of the mosquito.

"To combat them I concluded to set two barrels, each half filled with rainwater, side by side. One I left standing pure. To the other, I added one-half pound of paris green, and covered it with a screen wire mesh (one inch) to allow the mosquitoes to enter, but keep out any of the animals about the place.

"In a week the pure water barrel was alive with wiggletails, and the poisoned barrel did not have a trace of them. So I concluded that the larvae were poisoned, and never matured.

"I then, and from that day to this, in season, have kept poisoned water, protected against danger, about and around the premises, which in great measure destroyed the mosquito.

"This method of destroying the mosquito is inexpensive, and if generally used would almost annihilate them.

B. W. Marston, Sr."

This antedates the Barber and Hayne article by more than 5 years, and so far as known is the first record of the use of this arsenical as a mosquito larvicide. The actual tests were evidently carried out several years previously. As stated in his letter, Mr. Marston was a member of the State Crop Pest Commission of Louisiana, which was organized in 1904. I find that he was senior author with L. S. Frierson and Wilmon Newell of Circular No. 8 of this Commission, dated May 1906, dealing with paris green experiments against the boll weevil. The mosquito larvicide tests were probably carried out about this time also, or perhaps 15 years before the work of Barber and Hayne.

NEWS FROM UNION COUNTY, NEW JERSEY. Mr. William H. Randolph, Vice-President of the Commission died on October 20, 1951. Mr. Randolph had been a member of this Commission since January, 1919, and Vice-President since 1929. In 1924 he served as President of the New Jersey Mosquito Extermination Association. Mr. Randolph had always taken an active part in the activities of the Commission and freely spent his time to further this work in which he was so keenly interested.

Mr. Andrew J. Krog of Plainfield, N. J., a member of the Commission since 1936, resigned as his present business schedule prevented him from actively participating in Commission work.

Mr. Frank M. Doughty of Plainfield and Mr. Thomas Lowe of Roselle have been appointed to fill these two vacancies.

LT. COL. F. W. WHITTEMORE has left for Heidelberg where he will be Chief Entomologist in the European Theatre. His replacement in the Office of the Surgeon General at the Pentagon is Lt. Col. Ralph Bunn.

IN NORTH BANTEN, INDONESIA, 10,000 acres of rich rice land, deserted since the war because of endemic malaria, are being brought back into production after being sprayed with DDT. The spray teams were under the direction of the Indonesian Ministry of Health, Malaria Control Section. Supplies, equipment, and technical assistance were furnished by the Mutual Security Agency. It is planned that the people who have resettled the area will carry out permanent malaria control measures, such as repair of drainage ditches. The pre-war drainage system was destroyed by the Japanese.

The MSA Malaria Control Specialist and Entomologist in the area is Mr. Donald R. Johnson who is on leave of absence from his position as Assistant State Entomologist of the Minnesota Department of Agriculture, Dairy and Food. His address is U. S. STEM, c/o American Embassy, Djakarta, Indonesia.

RICHARD H. FOOTE recently received the degree of Doctor of Science from the Johns Hopkins School of Hygiene and Public Health and is now associated with Dr. Alan Stone at the U. S. National Museum where he is employed by the Division of Insect Detection and Identification, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

DR. DONALD J. PLETSCH of the International Health Division, U. S. Public Health Service recently left Washington for an assignment in Formosa. His address is W.H.O. Malaria Team, Taiwan Provincial Medical Research Institute, Ch'ao-Chou, Ping Tong, Formosa.

C. M. GJULLIN of the Bureau of Entomology and Plant Quarantine Corvallis, Oregon Laboratory in cooperation with the Bureau of Vector Control of the California State Department of Public Health has continued his studies of the resistance problem and has recently shown that in one district EPN applied by airplane has given excellent control of *Aedes nigromaculis* and *Culex tarsalis* which have shown resistance to DDT and toxaphene.

THE MOSQUITOES OF THE NORTHWESTERN STATES is the title of a bulletin which will be published soon by the Bureau of Entomology and Plant Quarantine. The authors are H. H. Stage, C. M. Gjullin, and W. W. Yates. This is a companion publication to THE MOSQUITOES OF THE SOUTHEASTERN STATES by King, Bradley and McNeel which has been so widely used.

EDITORIAL SECTION

In this issue, *Mosquito News* begins the presentation of the papers read at the Salt Lake City meetings. They are printed in the order of their appearance on the program insofar as the manuscripts were available at the time of the make-up of this number. If manuscripts were not turned in at the meetings and have not been received subsequently by the editor, or if they required extensive editing and revision, they could not be included in this number. It is expected that papers not published in the June issue will be published in September. . . .

The editor takes particular pleasure in presenting a timely paper by Mr. Van Derwerker as an editorial. Mr. Van Derwerker was a leading figure in the group of mosquito control workers who, some 12 years ago, feeling the need for a professional journal to serve their interests, founded *Mosquito News*.

At the same time, the editor wishes to call special attention to two other papers, which appear elsewhere in this issue, which are of similarly thought-provoking character—the kind which editors usually like to try to write themselves. One of these, "The Path of Least Resistance in California Mosquito Control," by Richard F. Peters, relates particularly to conditions in California, but has food for thought on the part of mosquito control men everywhere. The other paper, while appropriately enough particularizing on happenings in Florida, also has world-wide implications. It is entitled "Mosquito Control: Extensive versus Intensive Techniques," and is by Commander Hirst.

Paraphrasing a thought in the Peters paper, all three of the papers, which are here mentioned editorially, focus on the idea that we must avoid being content with merely *treating* the environment to reduce mosquitoes, but should, rather, return more often to the fundamental concept of *organizing* the environment to *prevent mosquitoes from occurring*. . . .

D. L. C.

MOSQUITO CONTROL AND ENGINEERING *

RALPH J. VAN DERWERKER

Sr. Sanitary Engineer, Federal Security Agency, Division of Sanitation, Public Health Service

Ample historical references illustrate Man's conflict with the mosquito, an insect which has influenced his selection of living, working and playing sites as much as any other single factor. Until the medical profession determined half a century ago that the mosquito was responsible for a number of annihilating disease outbreaks, the annoying nature of mosquito bites was insufficient for concerted and effective campaigns to eliminate the pest from the environment. However, as soon as the role of the mosquito in disease transmission was identified, community programs of mosquito control and extermination became a possibility and fact.

Entomologists furnished the knowledge of the life history of these insects, which made it possible to select the weakest point in the enemy's life cycle for extermination attacks. The weapons available at the time were most effective against the larval stage, which meant, in general, the elimination of breeding places or, where this was not possible, the extermination of larvae and pupae by chemical treatment. Elimination of breeding places meant removal of water or manipulation of water levels, and the skills needed for this type of work were found in the civil and sanitary engineering professions.

Large-scale programs of chemical applications and the vast marsh areas in New Jersey called for the development of special machinery not used in any other community work. The mechanical engineers came to the rescue with ditching machines, ditch-cleaners, special pumps, spraying and dusting equipment, mosquito traps and many special mechanical contrivances which contributed to the economy and effectivenes of mosquito control programs.

Engineering techniques in mosquito control have been primarily in the nature of an applied science. The most successful mosquito-fighting engineers have been and are those who expand their particular field of engineering to include basic elements of other sciences, such as entomology, chemistry, medicine, business administration, and many others. No professional man can be very successful in mosquito control work if he does not draw from other professions and skills. This is principally true in local campaigns which are restricted in scope by political boundaries and jurisdictions which, in turn, usually place a ceiling on available funds. As a result, existing mosquito control administration is limited to one or two professional employees who must resolve all the technical and administrative problems presented by the different fields of interest involved.

It is worthy of note here that, under the exigencies of World War II, the Public Health Service carried out a large-scale program against malaria which has virtually eliminated that disease from the United States through the use of teams of professionals—the doctor, engineer and entomologist. This was made possible through the availability of adequate funds.

The mosquito control program is in every sense an engineering problem. The planning, cost estimating, construction and operating techniques applied to the search for breeding places, to draining or filling, to impounded water control, and to chemical treatment of breeding areas or buildings depend essentially on engineering skills. Much equipment, material and labor is required to carry out the many operations required in an effective campaign. The engineer is trained from the outset to search for the most econom-

* Presented in panel on Mosquito Control at Annual Meeting of the Virginia Mosquito Control Association, January 25, 1952 at Norfolk, Virginia.

ical means to an effective solution and to weigh in every detail various plans to accomplish the desired result. He is also well trained to administer the execution of such plans and programs.

It has long been my considered opinion that a real need exists for engineering courses in mosquito control to equip graduating engineers with fundamentals in related sciences useful in mosquito control work. Sanitary engineering courses come closest to filling this need more because graduates of such courses have been exposed to the skills of many sciences than because they have been exposed to the specific sciences necessary to mosquito control. The broad scope of sanitary engineering training stimulates and equips the sanitary engineer for the multi-phase approach to mosquito control as no other technical education can. With the many positions in mosquito control work open in the United States and with the wide need for experts in this field throughout the world today, graduates of courses in mosquito control engineering should find no shortage of opportunities.

No community endeavor that neglects consideration of the mosquito menace is adequately protecting its own or its neighbor's interests. An engineer—municipal, highway or hydraulic—is usually involved in the conception of such public works and he cannot claim to be discharging his full responsibility when the impact of his plan on mosquito production is ignored. Impounded waters for water supply or electric power can, and frequently do, convert a healthy community to a malaria-ridden populace when the shore lines are not thoughtfully prepared beforehand. Highway and railroad culverts built a few inches too high can interrupt drainage to create vast and extremely productive mosquito breeding areas. Even that popular and well-known domestic engineer, the housewife, must guard against the subversive habits of the yellow-fever mosquito in certain climates. Every engineer must share the responsibility for guarding against the mosquito menace by learning its breeding habits and planning his project in such a way as to minimize the mosquito's chances for survival.

I have heard expressed the opinion that engineers are not necesary to malaria control work since the new residual insecticides have changed the techniques of malaria control. It is true that the customary mathematical and engineering skills required for drainage works are not needed in a residual spraying program. On the other hand, I know of no other professional group so well equipped as the engineers for planning the equipment, material and personnel necessary to carry out such work with efficiency and economy. It is also rare to find a locale where reliance on chemical treatment alone will prove to be the wisest course. It is short sighted to spend thousands of dollars annually applying residual treatments to buildings when a few hundred dollars might remove the source of breeding for all time.

I have attempted to bring out the importance of engineering skills to mosquito control work, whether applied by an engineer or others versed in engineering methods. Graduates of mosquito control engineering courses would be invaluable to the work and will find many opportunities to practice their profession. All engineers must be alert to the impact of their plans and works on mosquito production.

REVIEWS AND ABSTRACTS

Map of the World Distribution of Malaria Vectors. By Jacques M. May. Geographical Review, pp. 638–639, Oct. 1951. A bird's-eye picture of malaria vectors over the globe may be had by examining this map, 24 x 36 inches, published as Plate 3 in the Society's "Atlas of Diseases." Other sections of the map illustrate the distribution of malaria parasites, species of *Anopheles* locally distributed over Southern Europe, the Near East and Africa. The epidemiology of malaria is given in condensed form and a brief resume is included of the natural history of the total 53 species shown. A selected bibliography by countries is included. This rare contribution will be of much value to health officers, missionaries, explorers, and engineers, who need to know the prevalent vectors in a particular region and the type of malaria they can expect to find there.

The map will be of particular use to teachers who may wish to discuss malaria vectors and the basis for species eradication as well as to geographers who may desire to correlate the predominance of certain species with the geography of a particular region.

The author hopes soon to produce a second map showing the length of the transmission period in each malarious region and still later a map on how the various species of *Plasmodium* are distributed among their human hosts and finally a map showing who has malaria, in what numbers, at what age, and where. Of the 45 countries for which a selected bibliography is given, one cannot but wonder why the western hemisphere is represented by only Argentina.

The Geographical Review may be purchased from the American Geographical Society, Broadway at 156th Street, New York City 32 for $2 a number.—H. H. Stage.

Studies on Aqueous Suspensions of Insecticides. By A. B. Hadaway and F. Barlow. Bull. Ent. Res. 41(3):603–622. 1951. This well executed work is concerned with the important problem of particle sizes of insecticides (DDT, compound 497, and gammexane) as related to efficiency of their action against 2–3 day-old adult *Aëdes aegypti* females. A description of a plaster of paris block technique for testing purposes is given.

The authors have concluded that " . . . . the probability of a mosquito acquiring a lethal dose from a large number of small crystals distributed over an area is greater than from a small number of large crystals over the same area." They have indicated that the number of crystals of DDT picked up on the mosquito tarsi is dependent on particle size: the smaller the size the greater the pick-up. Apparently small DDT crystals are transferred from the legs to other body parts during cleaning activities. The authors found that mosquitoes which were stationary on DDT treated surfaces of plaster blocks pick up fewer crystals than those which walk over the same surface.

The authors have shown that shape and mass of DDT crystals influence pick-up and determine effectiveness, but that crystal length alone is not a critical factor. The investigation reported that effectiveness of compound 497 and of gammexane was much less influenced by particle size than DDT. The rapid penetration of these two substances makes retention of particles unnecessary.

Significantly the authors write ". . . the inverse relationship between particle size and effectiveness is not dependent on any property of DDT and is not peculiar to this insecticide."

The authors point out the practical applications that can be made from their findings: "Considerable improvement in the efficiency of DDT wettable powders can be achieved by limitation and reduction of the size of the DDT particles to the optimum of 10 to 20 microns. Particles of this size are easily suspended, and even at low dosages are present in sufficient numbers to provide effective and persistent deposits. On the other hand, it may be necessary to include a wider range of particle sizes in BHC wettable powders to obtain maximal efficiency for both initial and residual toxicity."—Jack Colvard Jones, National Institutes of Health, Bethesda 14, Md.

Studies on Aqueous Suspensions of Insecticides. Part II. Quantitative Determinations of Weights of DDT Picked Up and Retained. By F. Barlow and A. B. Hadaway. Bull. Ent. Res. 42(4):769–777. 1952. Like the other papers in this series of studies, this paper shows careful planning, precision in execution, and lucidity of expression. Adult *Aedes aegypti* females were exposed for variable periods of contact to deposits of aqueous suspensions of DDT crystals of different particle sizes sprayed onto plaster of paris blocks. The mean pick-up by a single mosquito, determined by the method of Schechter *et al.* (1945) was 0.48 microgrammes of DDT during an exposure of 30 seconds to 10–20 micron DDT crystals at a dose of 25 mg./ sq. ft. (320 mosquitoes tested).

The authors write: "Consideration of the kills in relation to the contact time shows that the 0–10 micron particles are less effective than those in the 10–20 micron range, and above 10 microns there is an inverse relation between particle size and effectiveness. When the amount picked up is taken into account, however, it is found that, weight for weight, the 0–10 micron particles are more effective than the 10–20 micron particles and that there is . . . an inverse relation throughout the range of particle size between particle size and effectiveness."

The authors present evidence to show that the *rate of action* of DDT is related to particle size and they suggest that "the solubility of DDT in

the cuticle waxes, and therefore penetration to the site of action, becomes more rapid as the crystal size decreases."

Significant differences were shown in the pick up of DDT crystals of the same size from different surfaces, *e.g.*, ". . . on plaster blocks, 0–10 micron DDT crystals are less effective than 10–20 micron crystals . . . for short contact periods. The reverse is true . . . when applied to mud blocks." They believe that these findings are due to differences in adhesion and to differences in surface irregularities. DDT crystal pick-up by mosquitoes was four times greater on plaster than on glass.—Jack Colvard Jones.

OBSERVATIONS ON THE MOSQUITOES OF EDOGAWA AREA. I. SEASONAL OCCURRENCE; II. ZOOPHILISM. (In Japanese.) By Sasa, Manabu; Hosoya, Hideo; Kano, Rokuro; Hayashi, Shigeo; Oyama, Kazuo; Miura, Akiko; and Kimura, Mari. Jap. J. San. Zoology (Eisei Dobutsu). 1(1):20–22. 1950. (Pub. by the Japan Soc. of San. Ent., c/o Research Inst. for Nat. Resources, 4-Chome, Hyakunincho, Shinjuku-ku, Tokyo. $2.00.) I. Seasonal occurrence: Adult mosquito collections were made in an industrial zone of Tokyo, using animal traps at night, and a specific type of frequency was noted for each species. Only one peak was noted for each species in a year: for *Culex pipiens* it ran from May through August; for *C. tritaeniorhynchus* it extended from the middle of July to the middle of August; for *Aedes vexans* it ran from the middle of June to the middle of August; and for *Anopheles hyrcanus sinensis* it extended from the middle of June to the beginning of August. II. On the basis of mosquitoes entering animal traps *C. tritaeniorhynchus, A vexans,* and *A. h. sinensis* found the goat most attractive, and the rabbit and hen less so. It was found by examination of engorged mosquitoes that *A. h. sinesis* selected hosts in the following order: goat>rabbit>chicken. *Culex pipiens* did not show distinct host selection among the animals used in baiting the animal traps.—Toychi Okada, Japan, and Don Pletsch, WHO, Taiwan.

ON SOME MORPHOLOGICAL CHARACTERS IN MOSQUITO PUPAE. (In Japanese.) By Asanuma, Kiyoshi. Jap. J. San. Zoology (Eisei Dobutsu). 1(1):15–16. 1950. (For publisher and price, see first abstract of this series.) The postero-median projection of the 8th abdominal tergum and the vertical plate of mosquito pupae were found to be important morphological criteria. The postero-median projection is broad and oblong, not projecting posteriorly in Anophelini, while it is semi-circular, hemi-spindle shaped or hemi-elliptical, projecting posteriorly in Culicini. In the Culicini two types are differentiated: the *Aedes* type (*Aedes, Uranotaenia, Armigeres, Tripteroides*) with lateral margin not well developed and posterior margin prominently produced; and the Culex type (*Culex, Theobaldia*) with lateral margin well-developed and posterior margin not prominently produced. In the Anophelini the vertical plate is homogeneous in structure; in Culicini the lateral part is more chitinized than the central part.—Okada and Pletsch.

A REPORT ON THE ERADICATION OF ANOPHELINE LARVAE BY MEANS OF PARIS GREEN, A LARVICIDE, IN THE VICINITY OF HANKOW, CENTRAL CHINA. (In Japanese.) By Mashiko, Kikuya. Jap. J. San. Zoology (Eisei Dobutsu). 1(1):12–13. 1950. (For publisher and price, see first abstract of this series.) In Central China, a swamp covering 4 square kilometers was dusted with paris green 3 or 4 times a month from May 1941 through December 1942. Numbers of larvae were reduced to 6 to 16% of those of the previous year. After the dusting, the larvae did not show any increase even in October, when they would ordinarily have attained maximum numbers.—Okada and Pletsch.

SOME FACTORS AFFECTING THE AVAILABILITY OF CONTACT INSECTICIDES. By F. Barlow and A. B. Hadaway. Bull. Ent. Res. 43(1):91–100. 1952. In this paper the authors indicate that DDT in oil can be crystallised by insects walking over treated surfaces, crystallisation being more rapid with the purity of the DDT, and being more rapid with films than with droplets of oil. After crystallisation on non-absorptive surfaces (glass, wire, etc.) there is a considerable reduction in toxicity, and this work suggests that "It is possible that many of the reported synergistic effects with DDT are due to inhibition of crystallisation . . . by the various materials added."

It was found that oil suspensions of DDT were more effective than crystals alone (optimum size from 10–20 microns) on a non-absorptive surface.

This investigation showed that DDT crystals on compressed fibreboard project upward at right angles from the fibers and are apparently readily available to insects, whereas DDT crystals on glass surfaces lie in the plane of the treated surface and, presumably, are not readily available.

Crystallisations from single drops of 5 percent DDT in kerosene were shown to occur more extensively on fibreboard and filter paper (kind not specified) than with other materials tested. DDT crystals on cardboard, cork, velvet and Essex board were considerably smaller. No detectable crystallisation occurred on mud blocks treated with DDT.

A study of 38 different solvents containing DDT showed that the behaviour of this insecticide on fibreboard depended on the physical characters of the solvent (*e.g.*, volatility) rather than on constitution.

The authors suggest that reduction in availability of insecticides on addition of inert diluents may be a masking effect. Probability of lethal adherence of insecticidal particles becomes less as proportion of inert particles increases.

This paper presents evidence to show that dry DDT dust on plaster blocks is not affected by relative humidity whereas deposits from aqueous suspensions are significantly affected.—J. C. Jones.

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